DOE 2018

Mechanisms of Pacific Decadal Variability (PDV) in ESMs

by Emanuele Di Lorenzo, Sam Stevenson, and Matt Newman

Georgia Tech Ocean Science & Engineering

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GOALS:

1) Identify and compare the **mechanisms that energize tropical** and **extra-tropical** Pacific decadal variance in each CMIP5 ESM

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GOALS:

1) Identify and compare the **mechanisms that energize tropical** and **extra-tropical** Pacific decadal variance in each CMIP5 ESM

2) Diagnose how these mechanisms are projected to change under anthropogenic forcing using **large-ensembles**

Mechanistic Hypothesis of PDV processes

(Constrained by Observations)

Tropical Pacific Decadal Variability (TPDV) Hypothesis #1

Extra-tropical Pacific Decadal Variability (EPDV) Hypothesis #2

Mechanistic Hypothesis of PDV processes

(derived from Observations)

Tropical Pacific Decadal Variability (TPDV) Hypothesis #1

TPDV HYPOTHESIS #1:

Seasonal stochastic variability of ***extra-tropical ENSO precursors*** is reddened by ENSO and its teleconnections into decadal variance.

GOAL

Quantify the ENSO precursor contribution to TPDV

Tropical Pacific Decadal Variability (TPDV) Hypothesis #1

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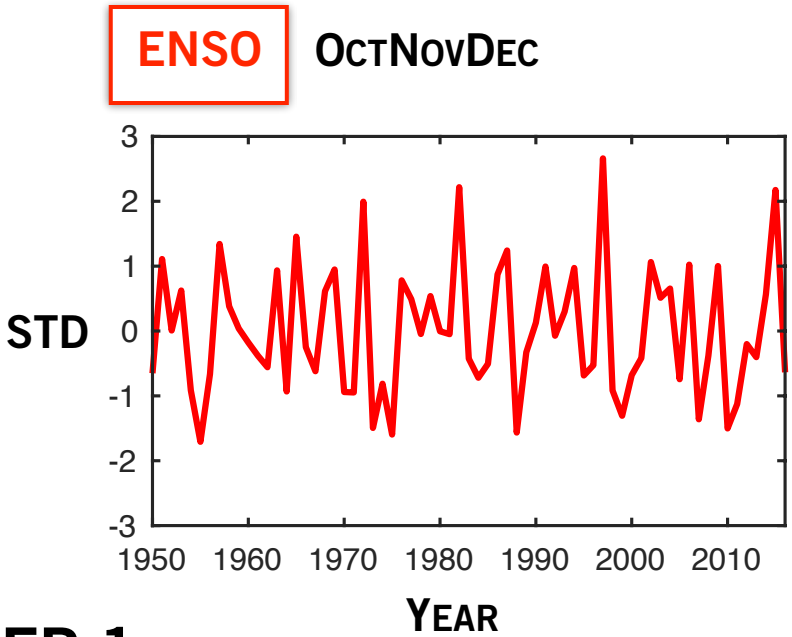
Seasonal stochastic variability of ***extra-tropical ENSO precursors*** is reddened by ENSO and its teleconnections into decadal variance.

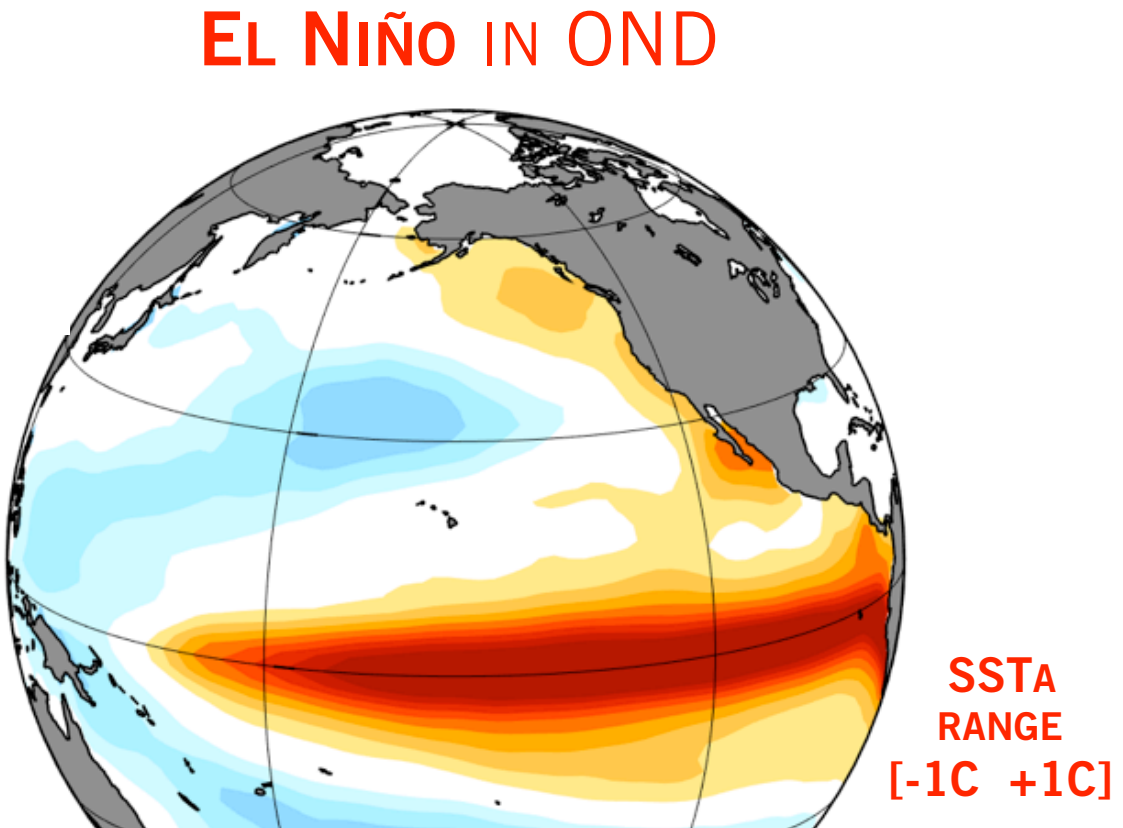
GOAL

Quantify the ENSO precursor contribution to TPDV



STEP 1

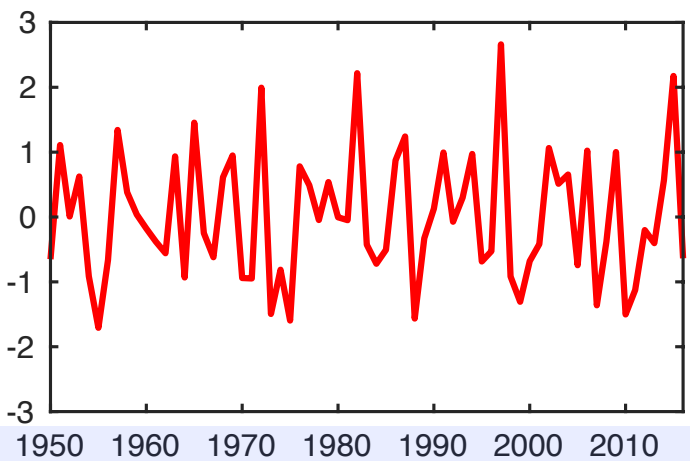
Define an index of ENSO in the peak phase (OND)



ENSO Precursors

North Pacific

ENSO OctNovDec

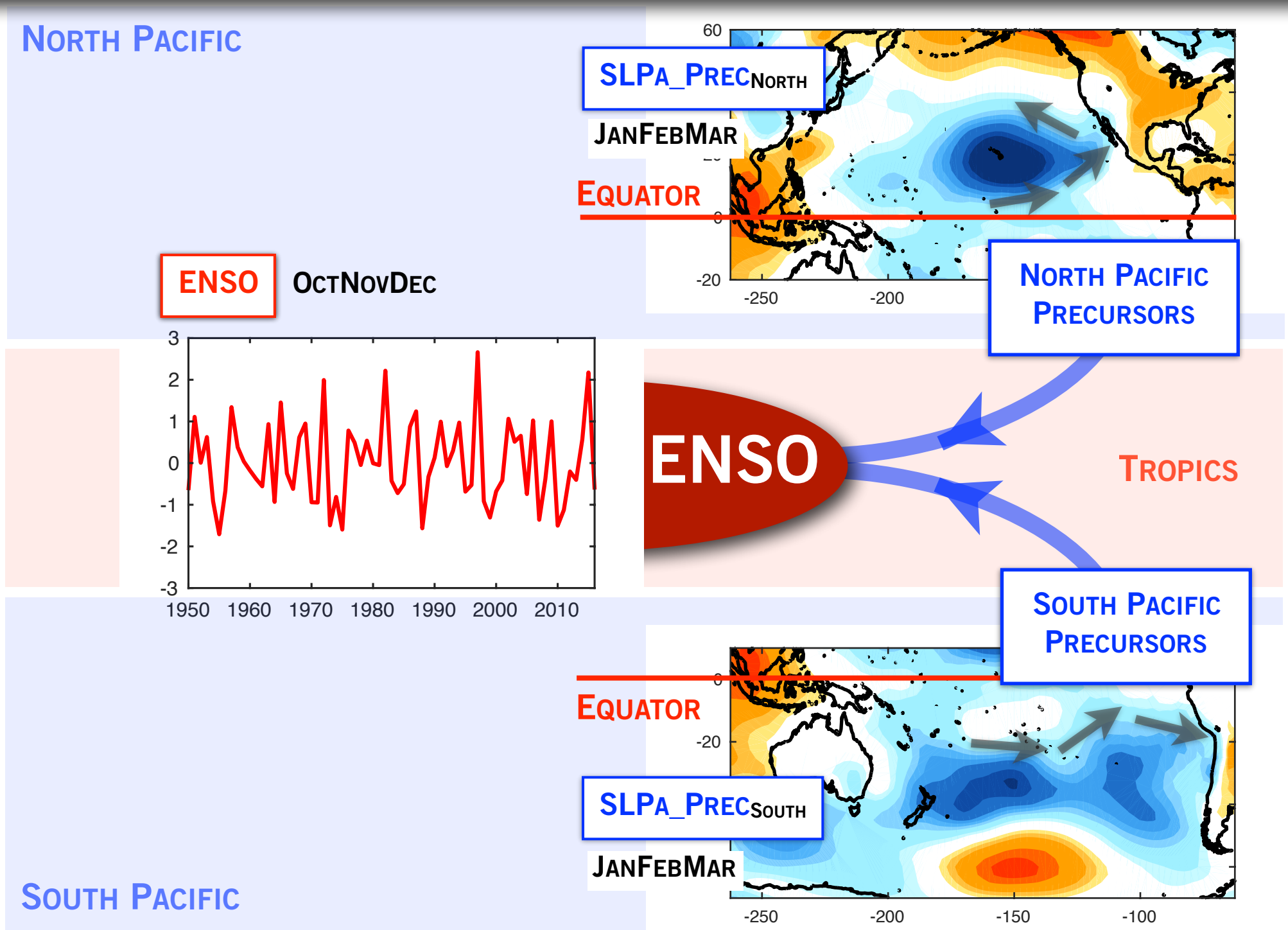


ENSO

Tropics

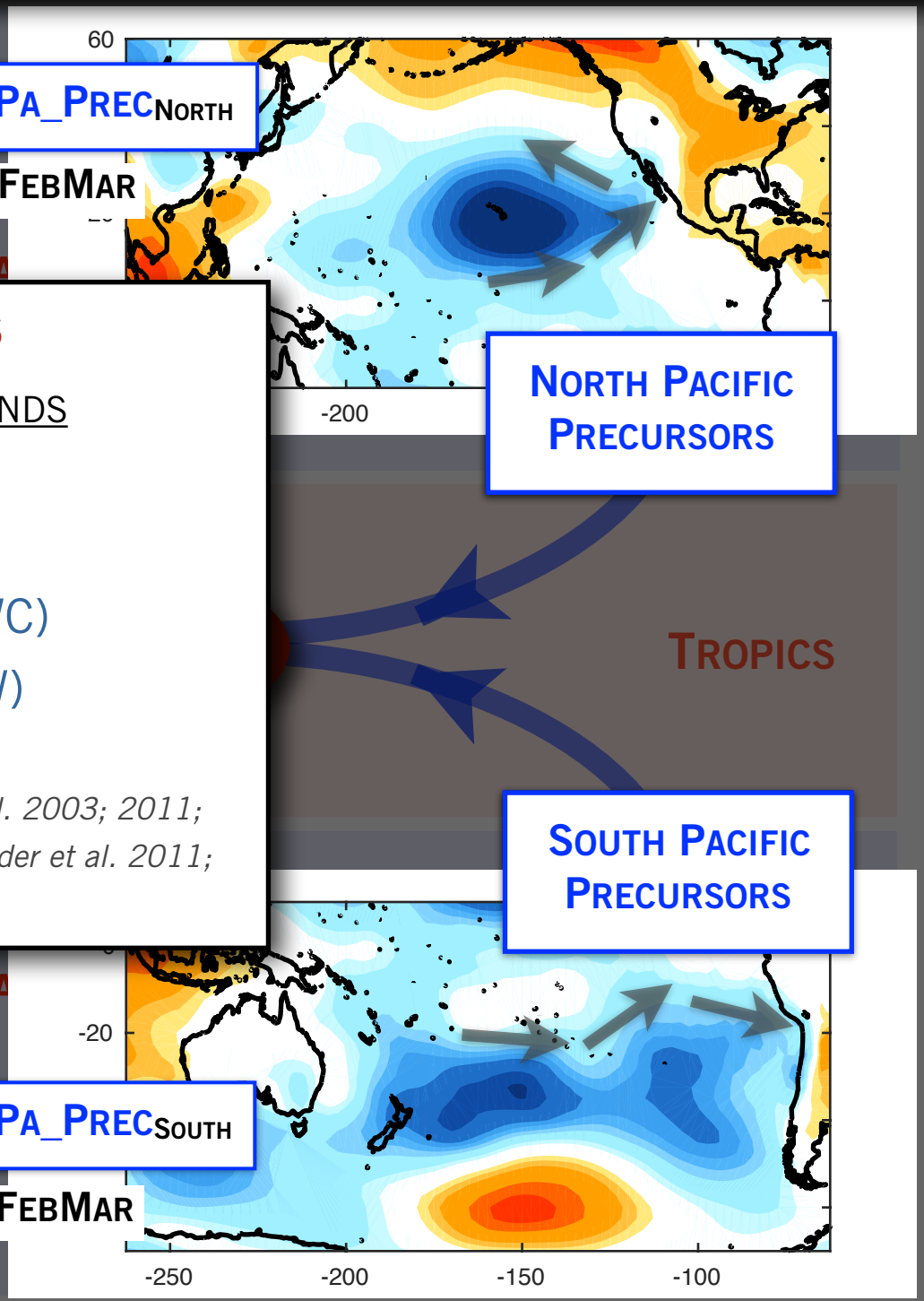
South Pacific

ENSO Precursors



ENSO Precursors

North Pacific



ENSO Precursor Dynamics

Weakening off-equatorial Trade Winds

Meridional Modes (MMs)

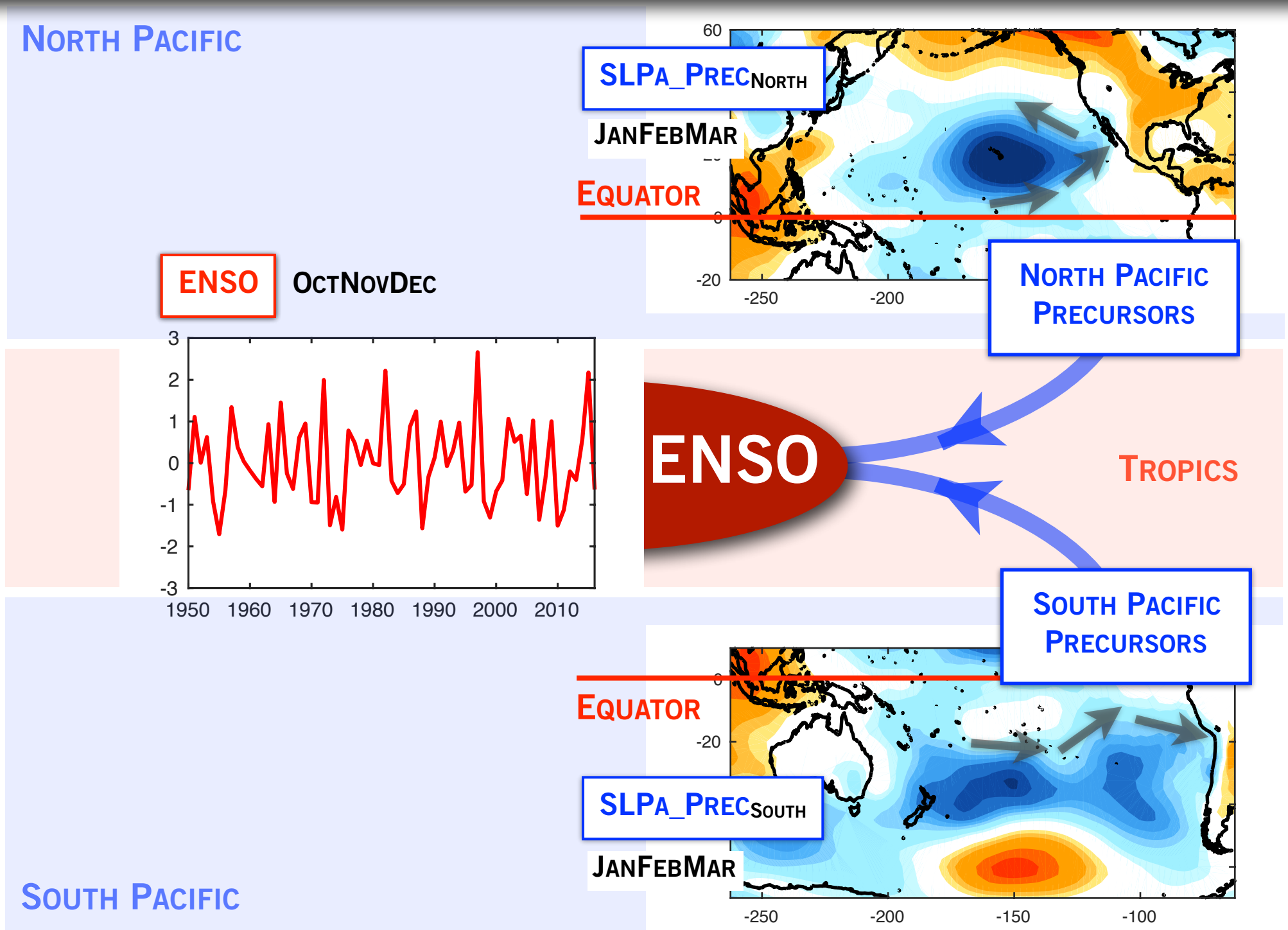
Trade Wind Induced Charging (TWC)

Off-equatorial Rossby Waves (RW)

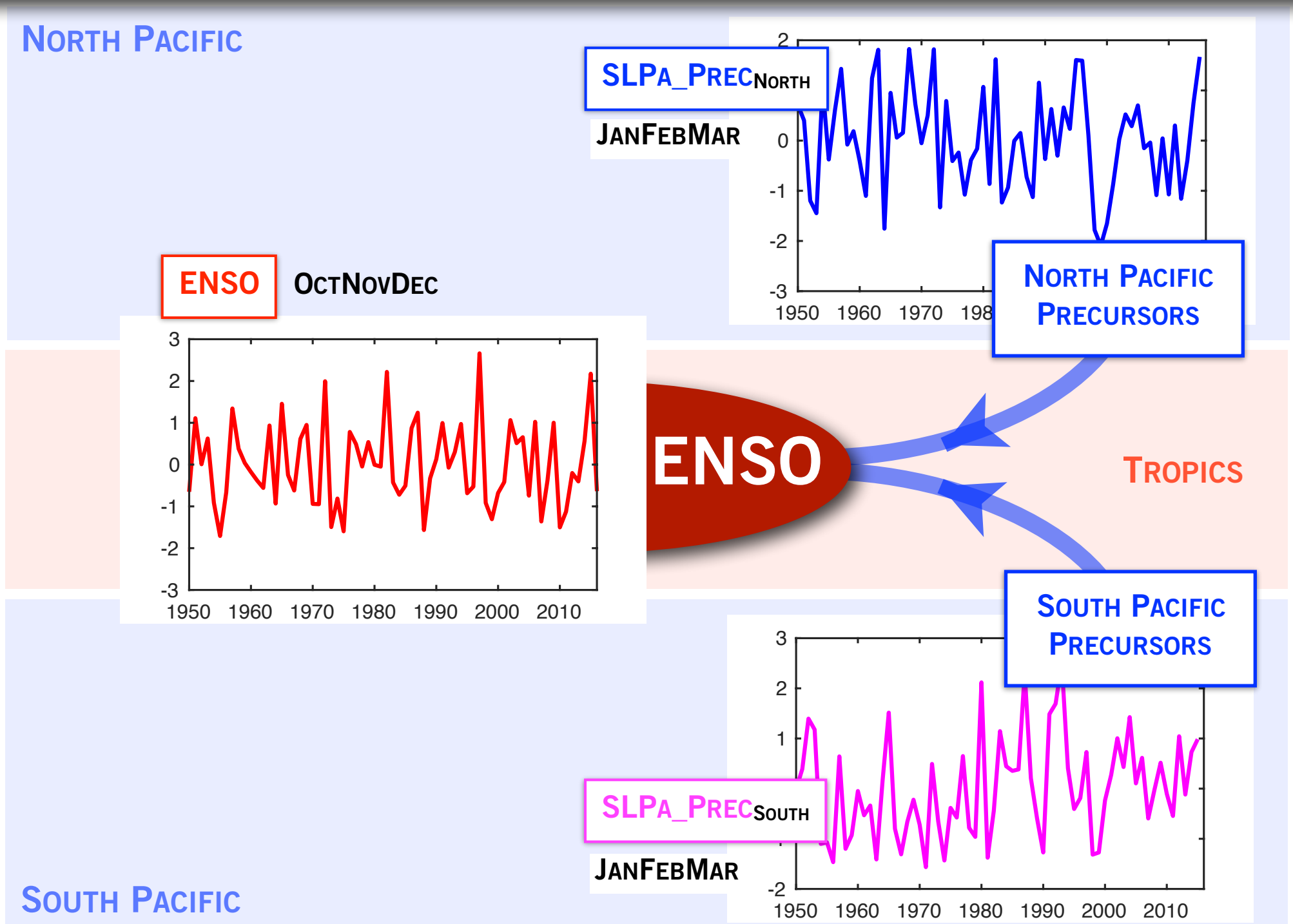
Penland et al. 1995; Knutson and Manabe, 1998; Vimont et al. 2003; 2011; Anderson et al. 2003; 2011; Chiang and Vimont, 2004; Alexander et al. 2011; Zhang et al. 2014; Di Lorenzo et al. 2015

South Pacific

ENSO Precursors



ENSO Precursors

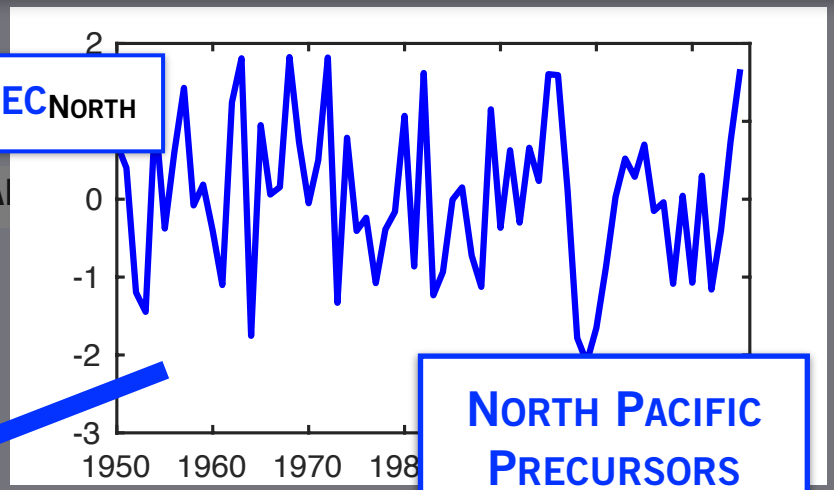


ENSO Precursors

North Pacific

SLPa_PrecNorth

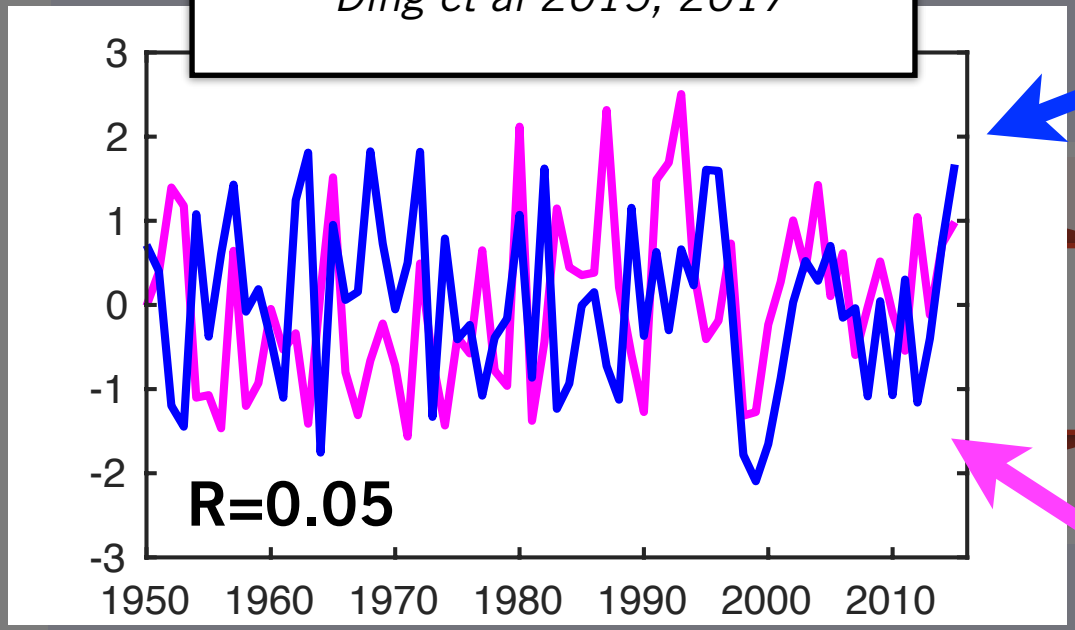
JanFebMar



North Pacific Precursors

No Correlation

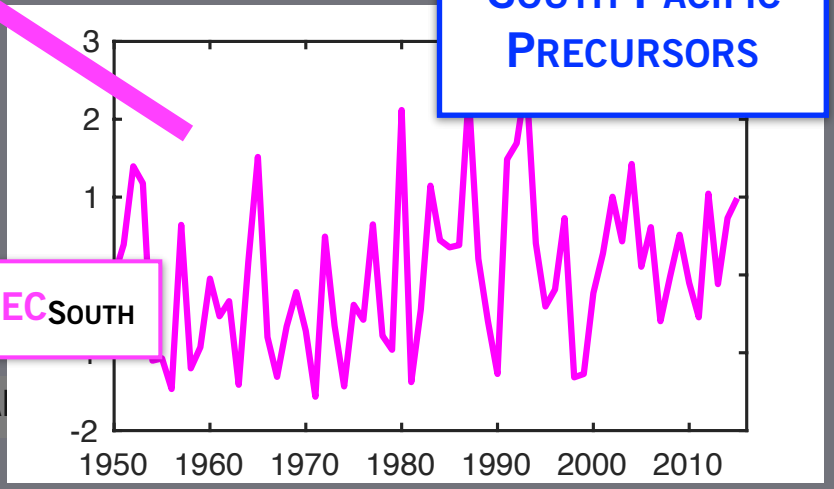
Ding et al 2015; 2017



Zonal Modes

Tropics

South Pacific Precursors



SLPa_PrecSouth

JanFebMar

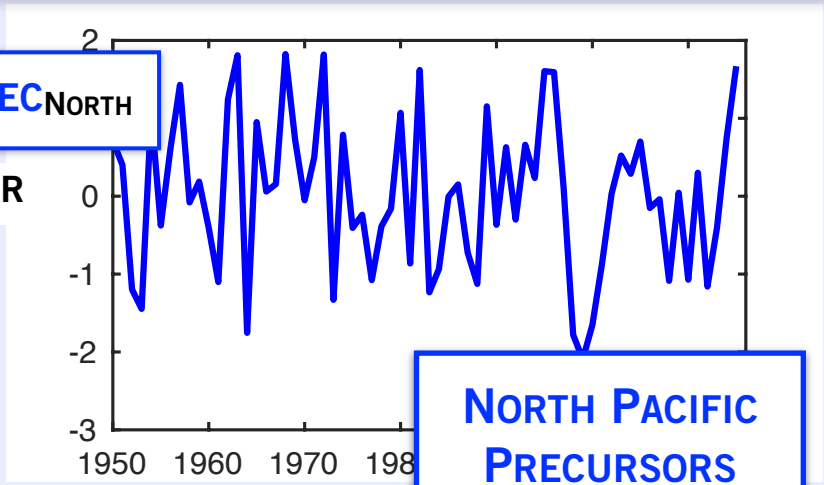
South Pacific

ENSO Precursors

North Pacific

SLPA_PRECNORTH

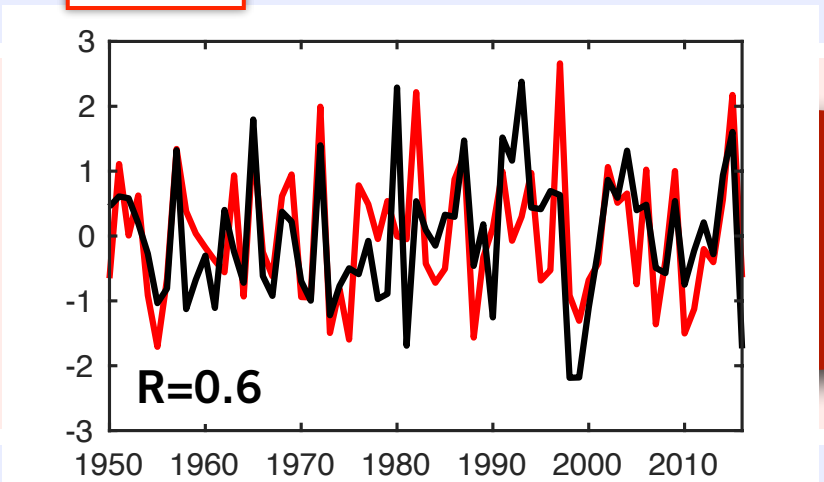
JANFEBMAR

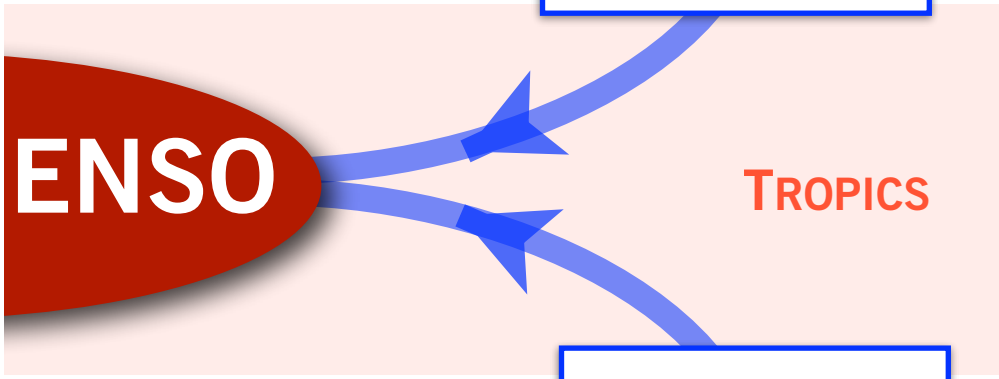


North Pacific Precursors

ENSO

OCTNOVDEC



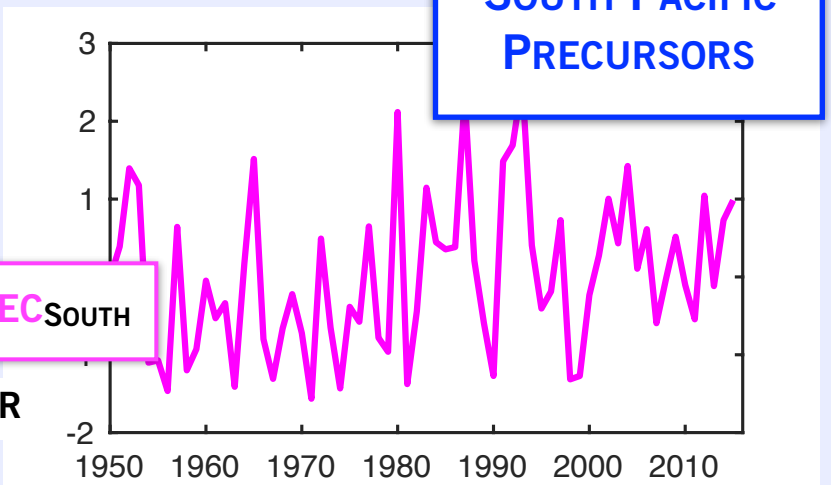


South Pacific Precursors

$$ENSO_{REC} = 0.5*SLPA_PREC_{NORTH} + 0.5*SLPA_PREC_{SOUTH}$$

SLPA_PRECSOUTH

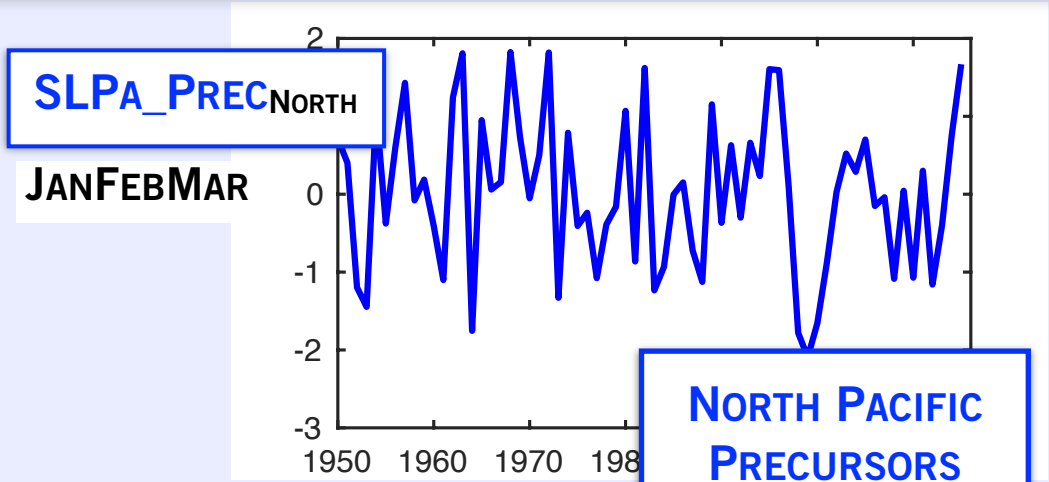
JANFEBMAR



South Pacific

ENSO Precursors

North Pacific

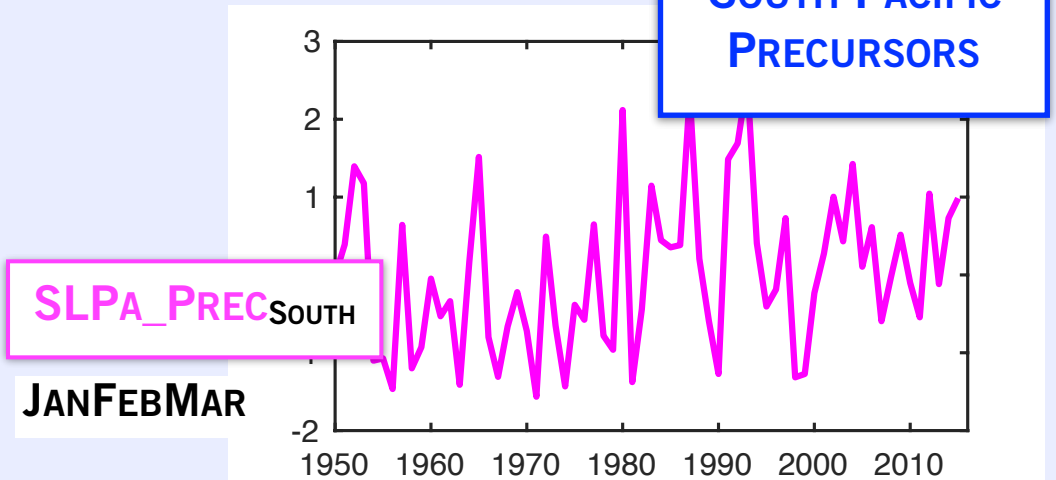


North Pacific Precursors

Tropics

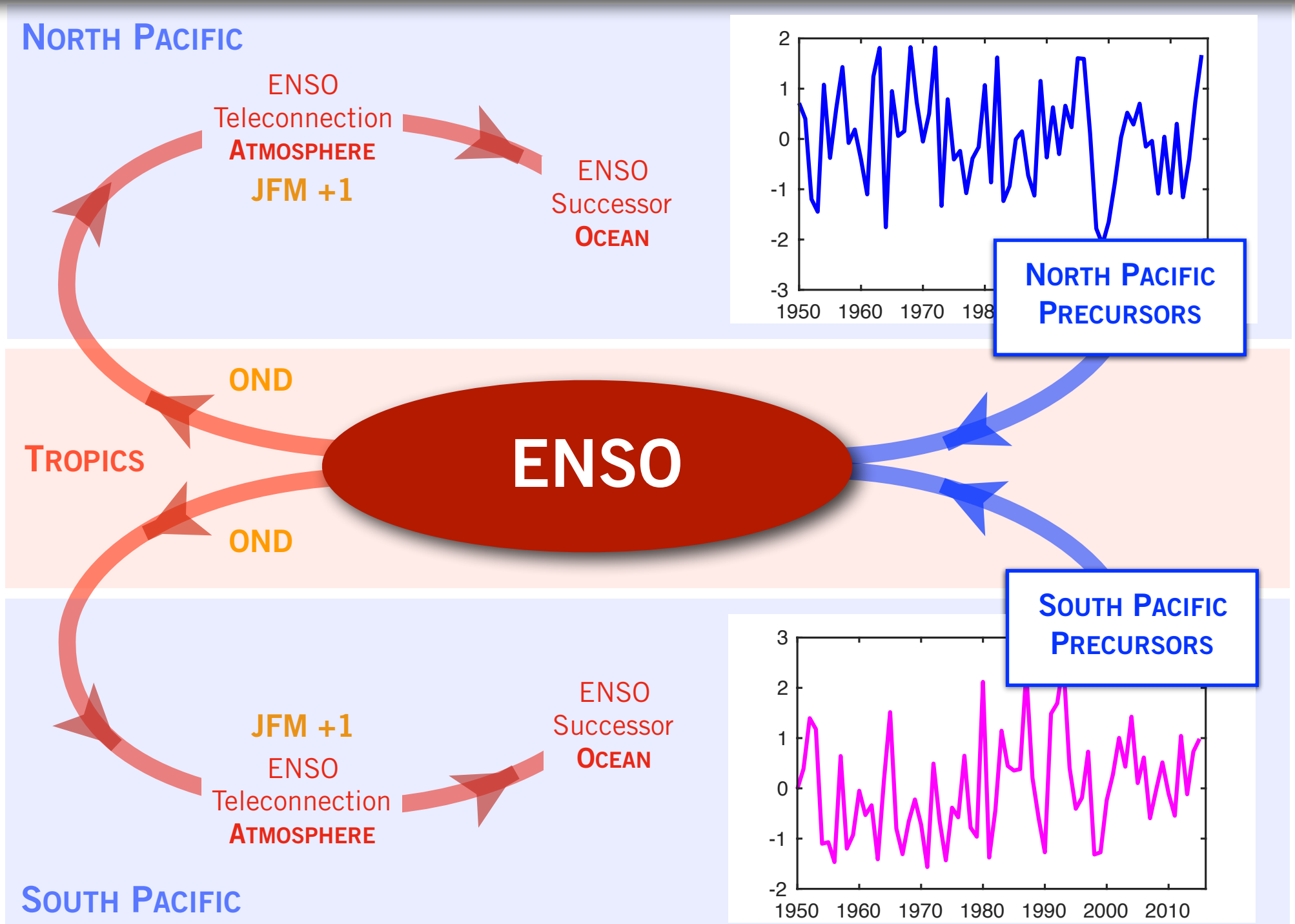
ENSO

South Pacific Precursors



South Pacific

The reddening of ENSO Precursors



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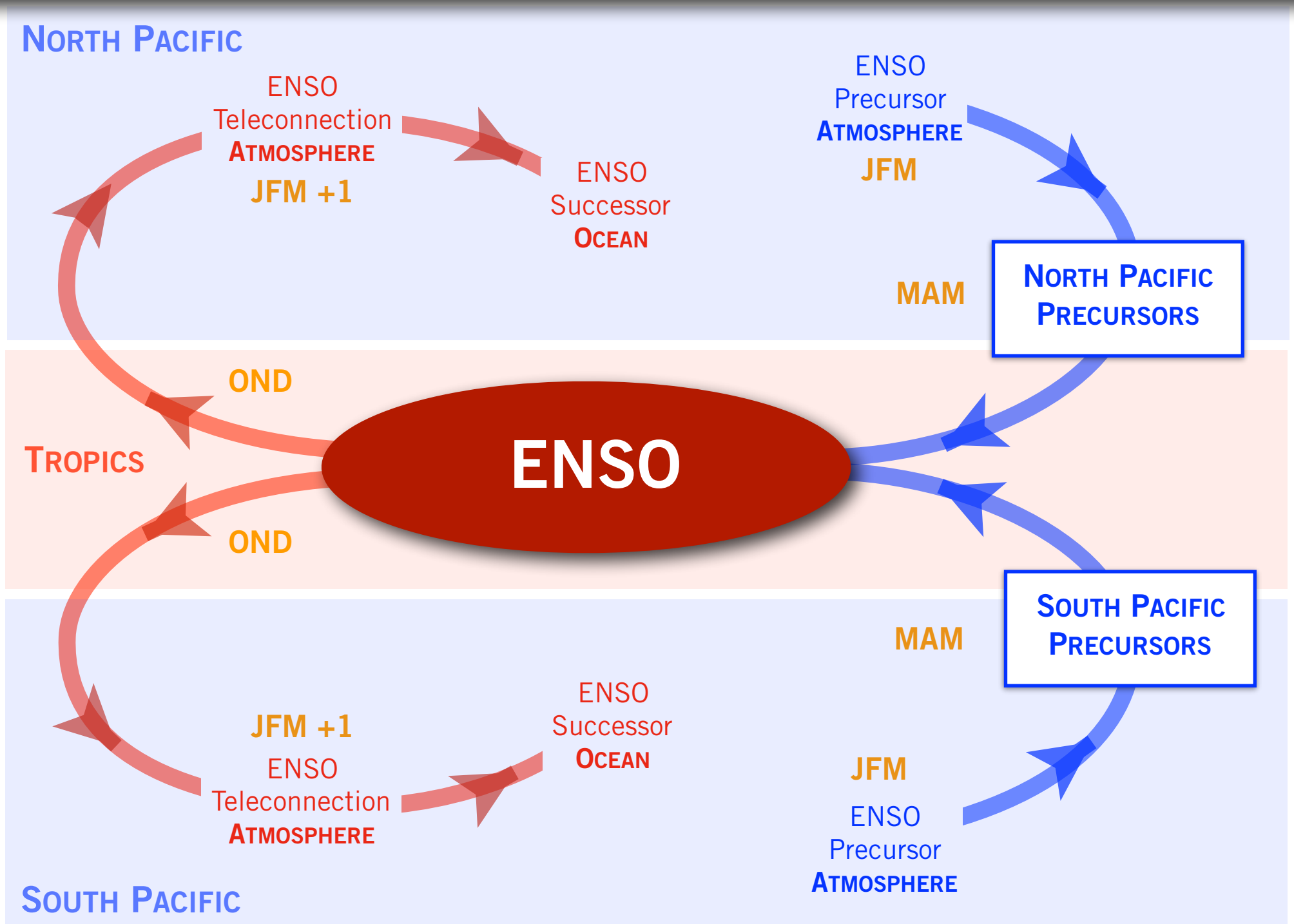

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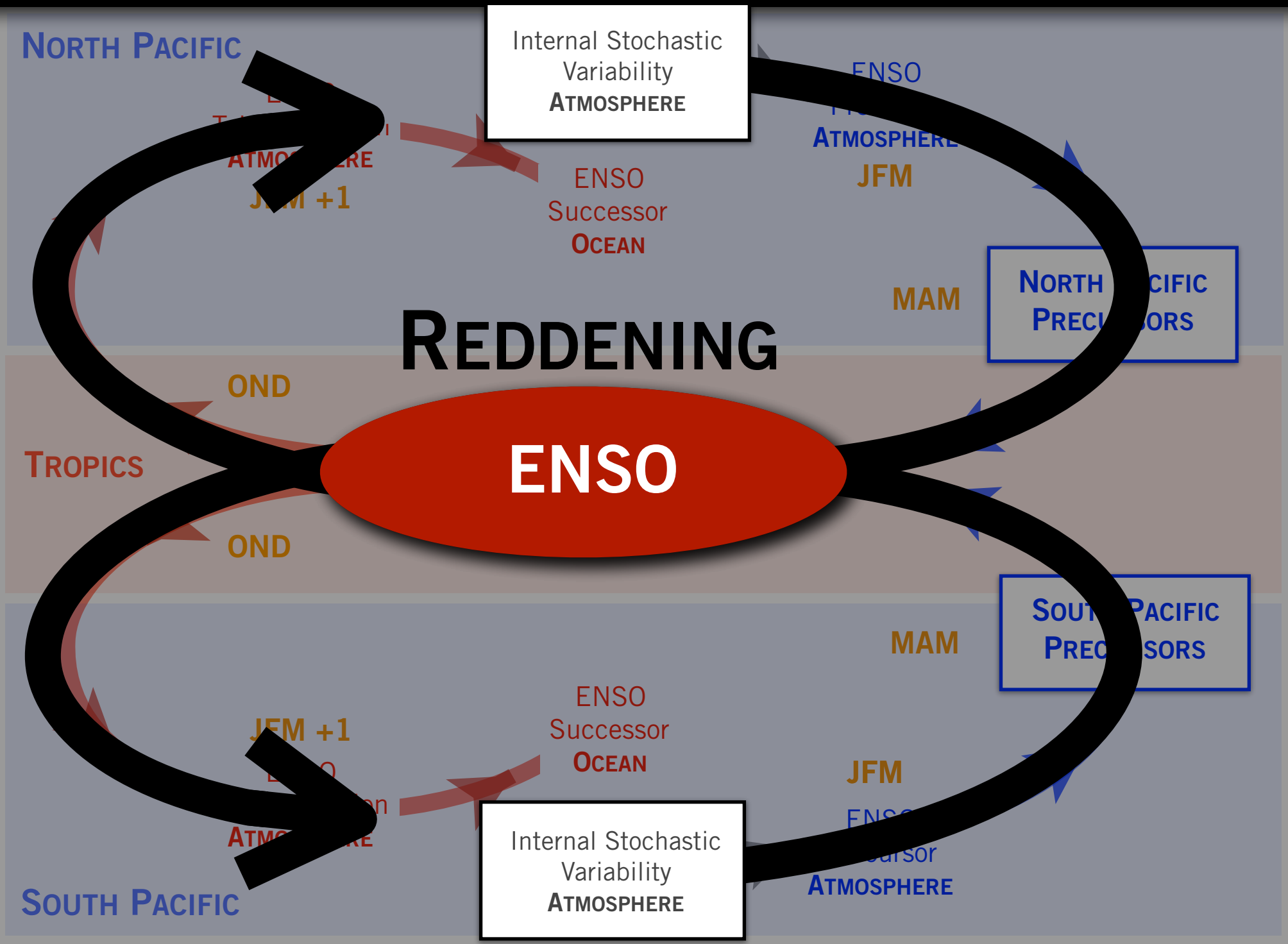

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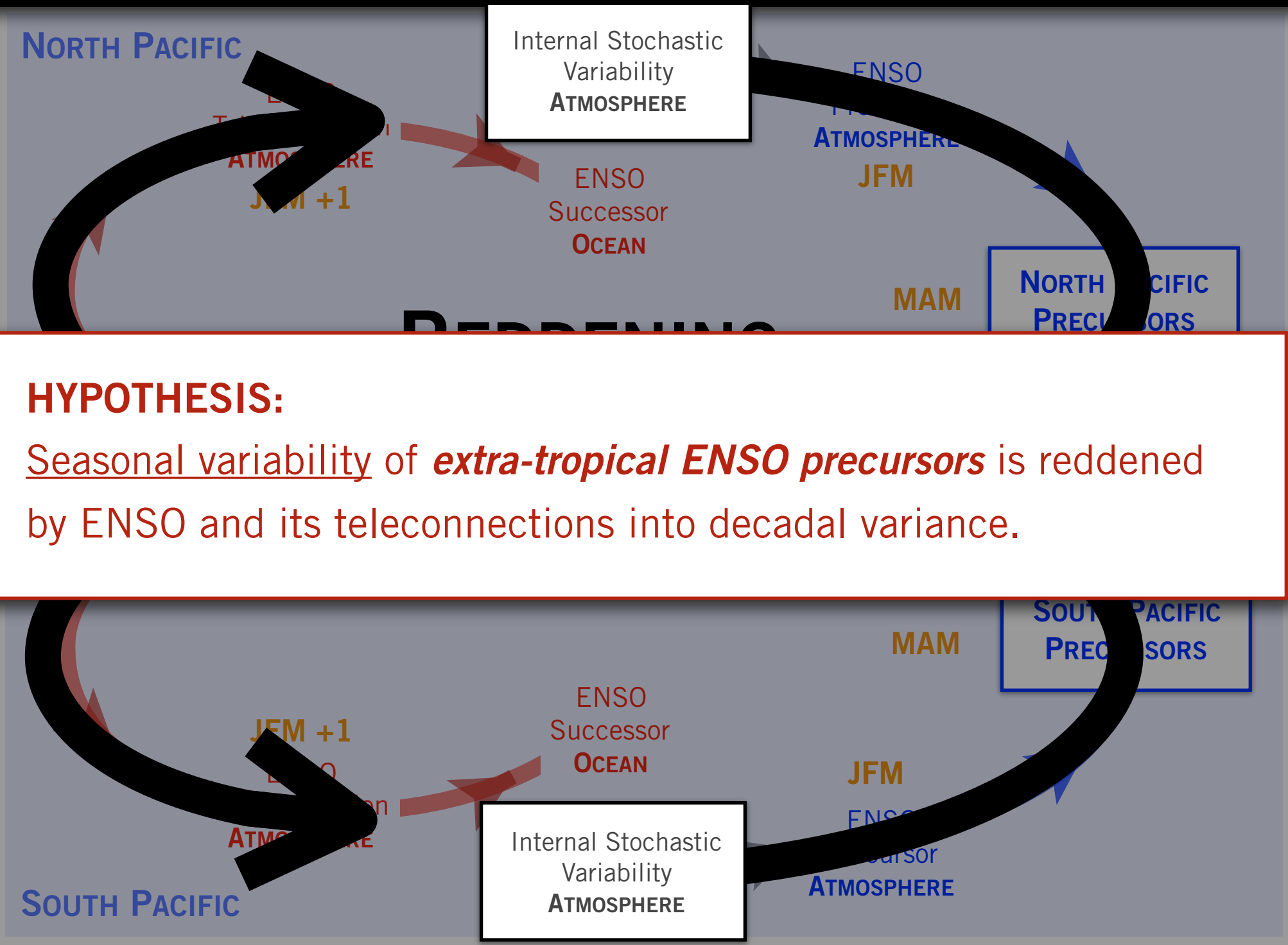
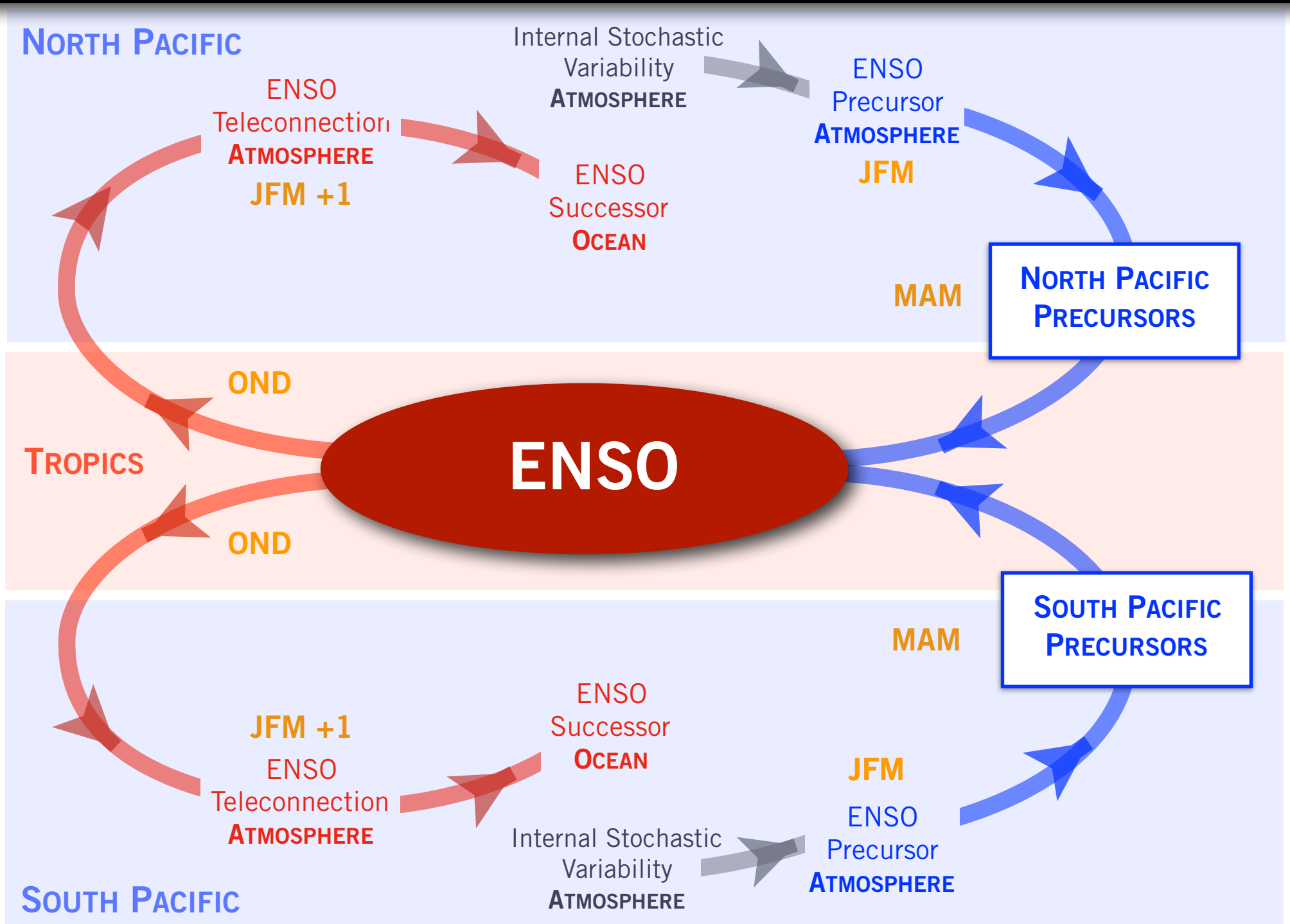


HYPOTHESIS:

Seasonal variability of ***extra-tropical ENSO precursors*** is reddened by ENSO and its teleconnections into decadal variance.

The reddening of ENSO Precursors



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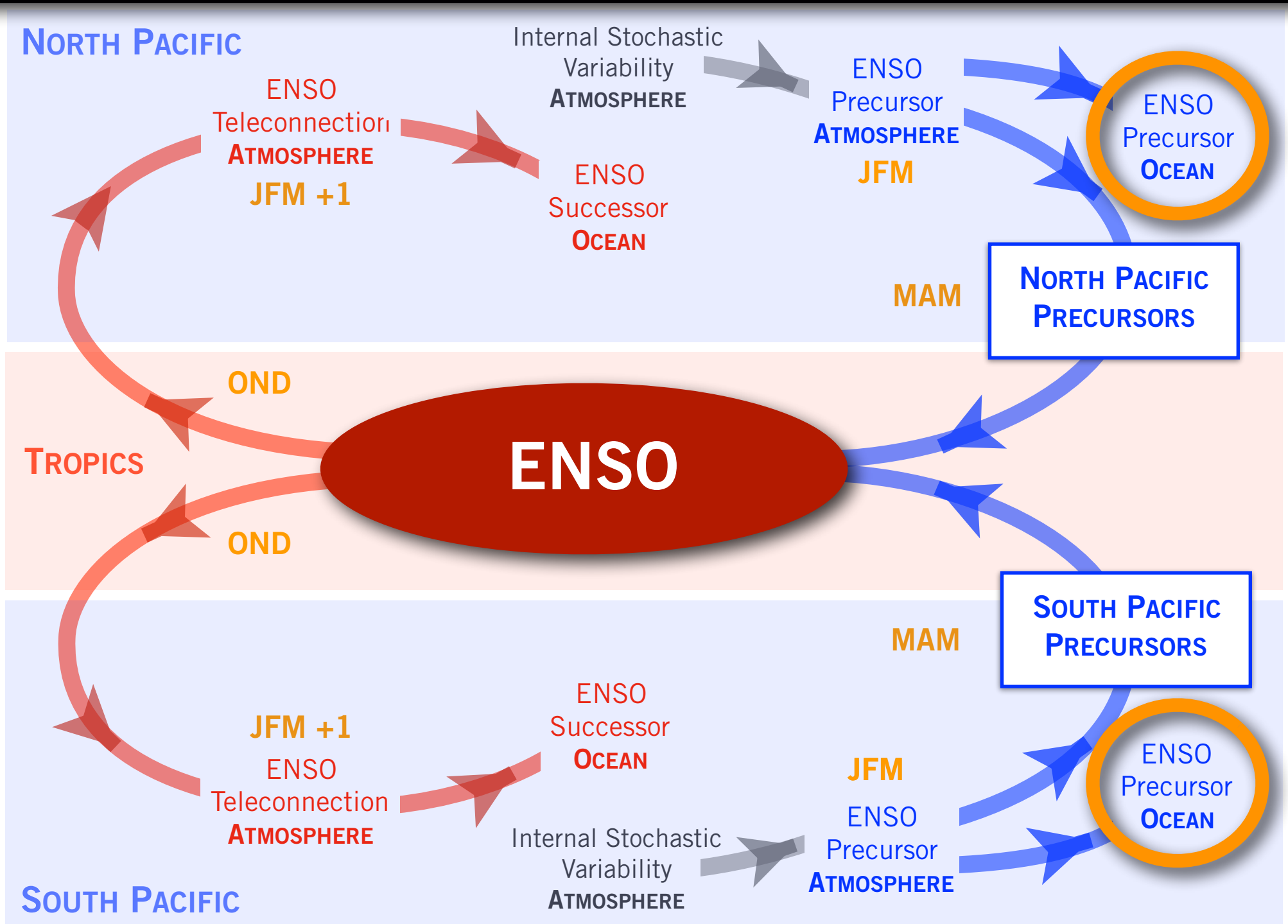

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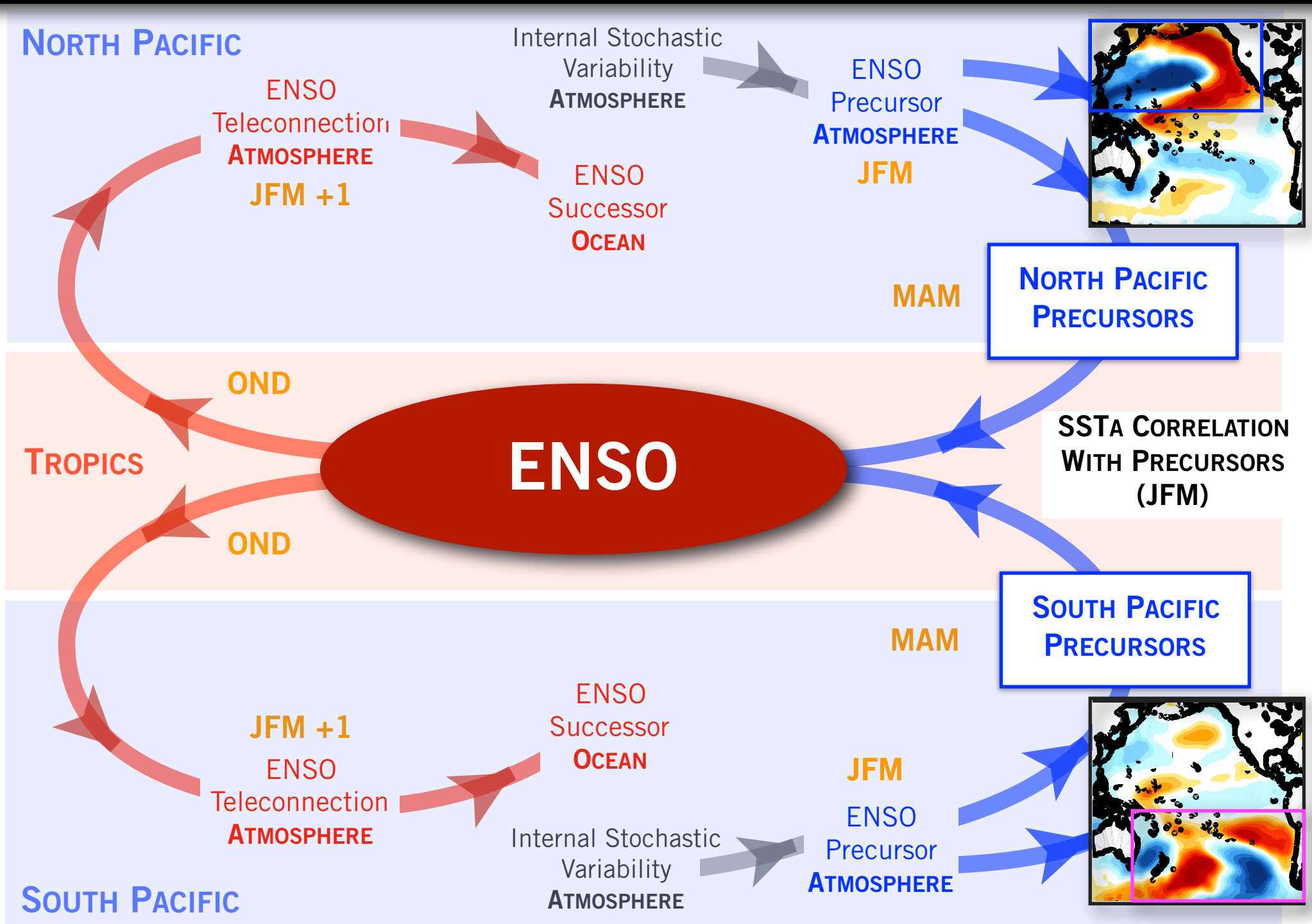

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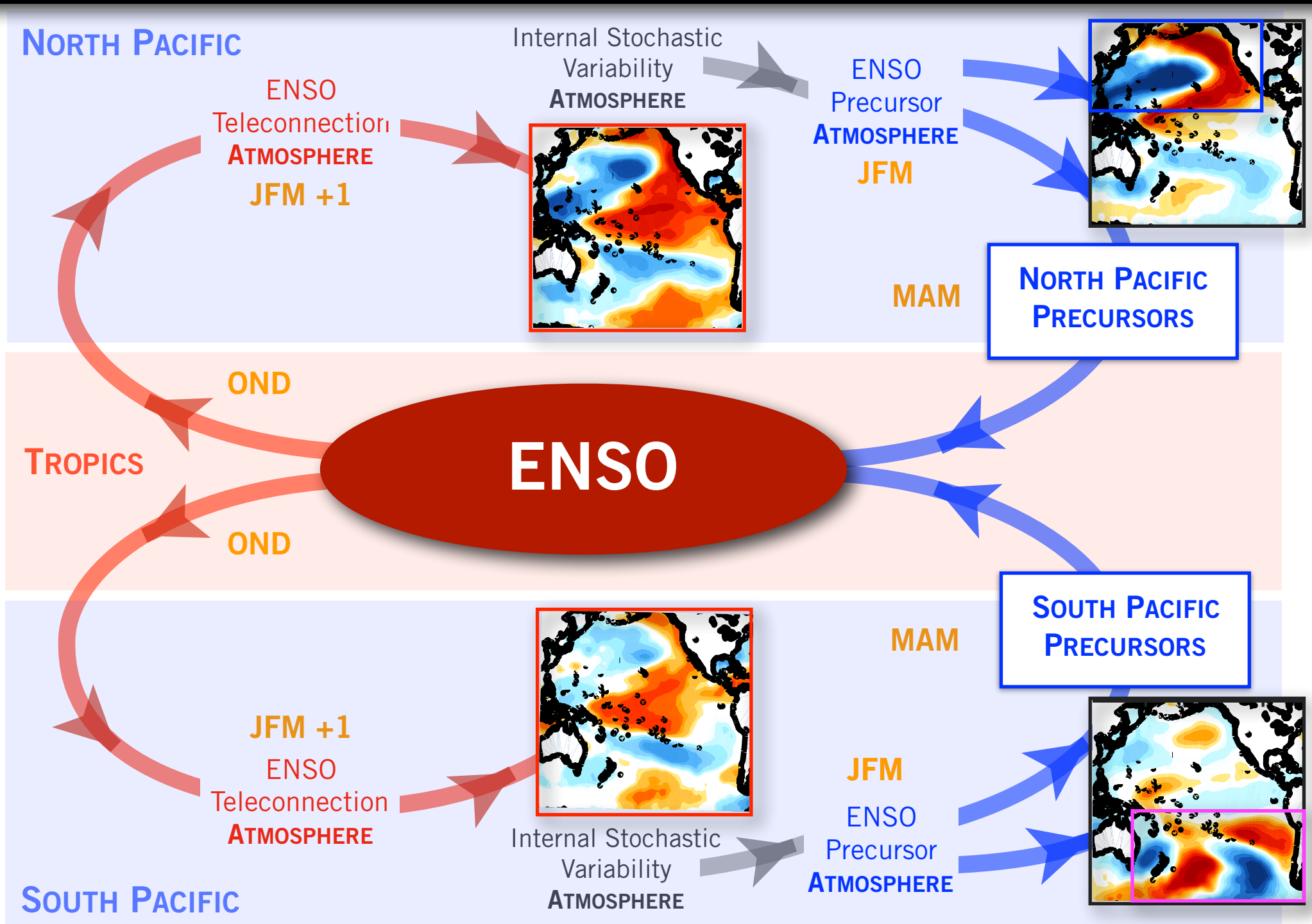

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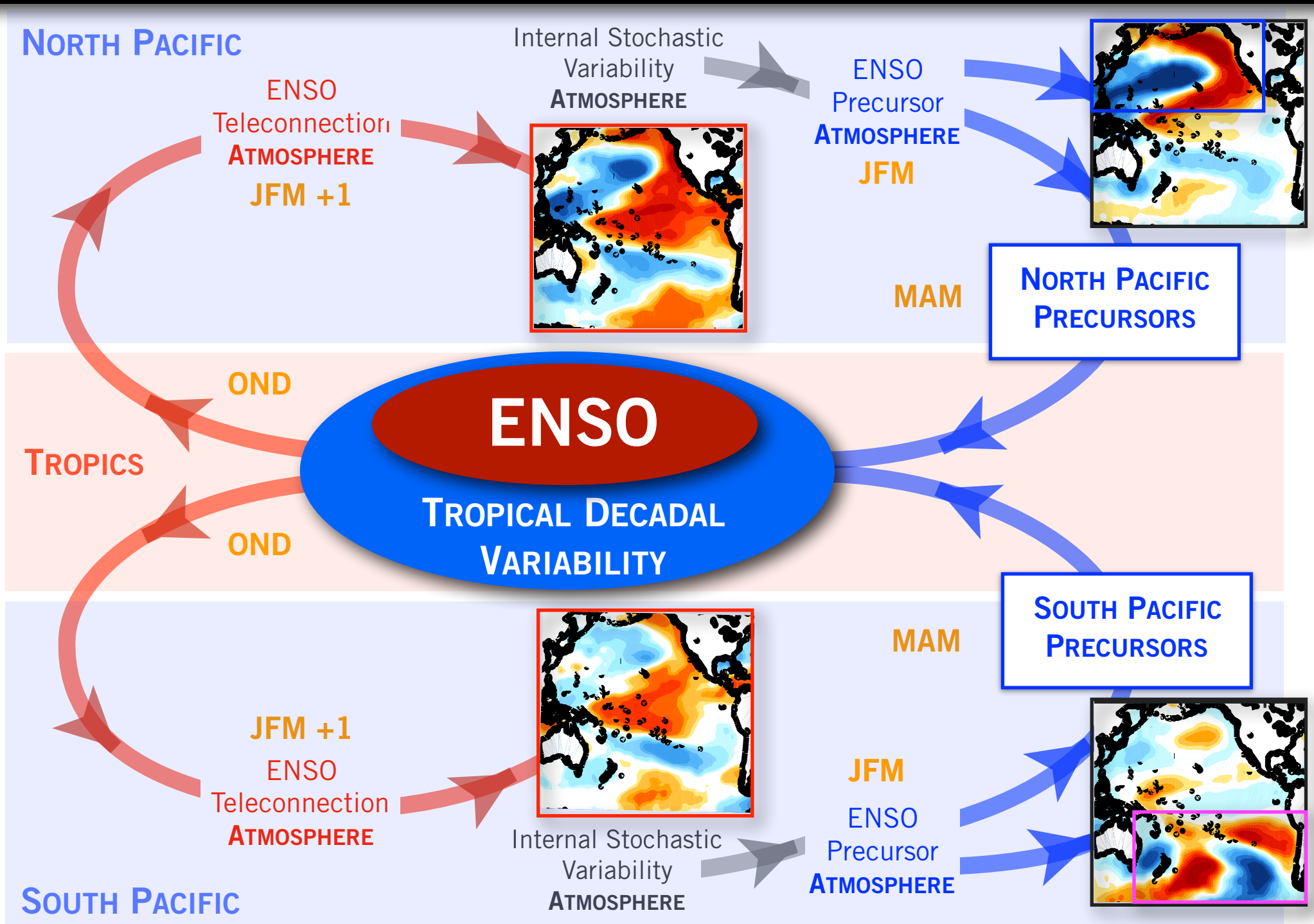

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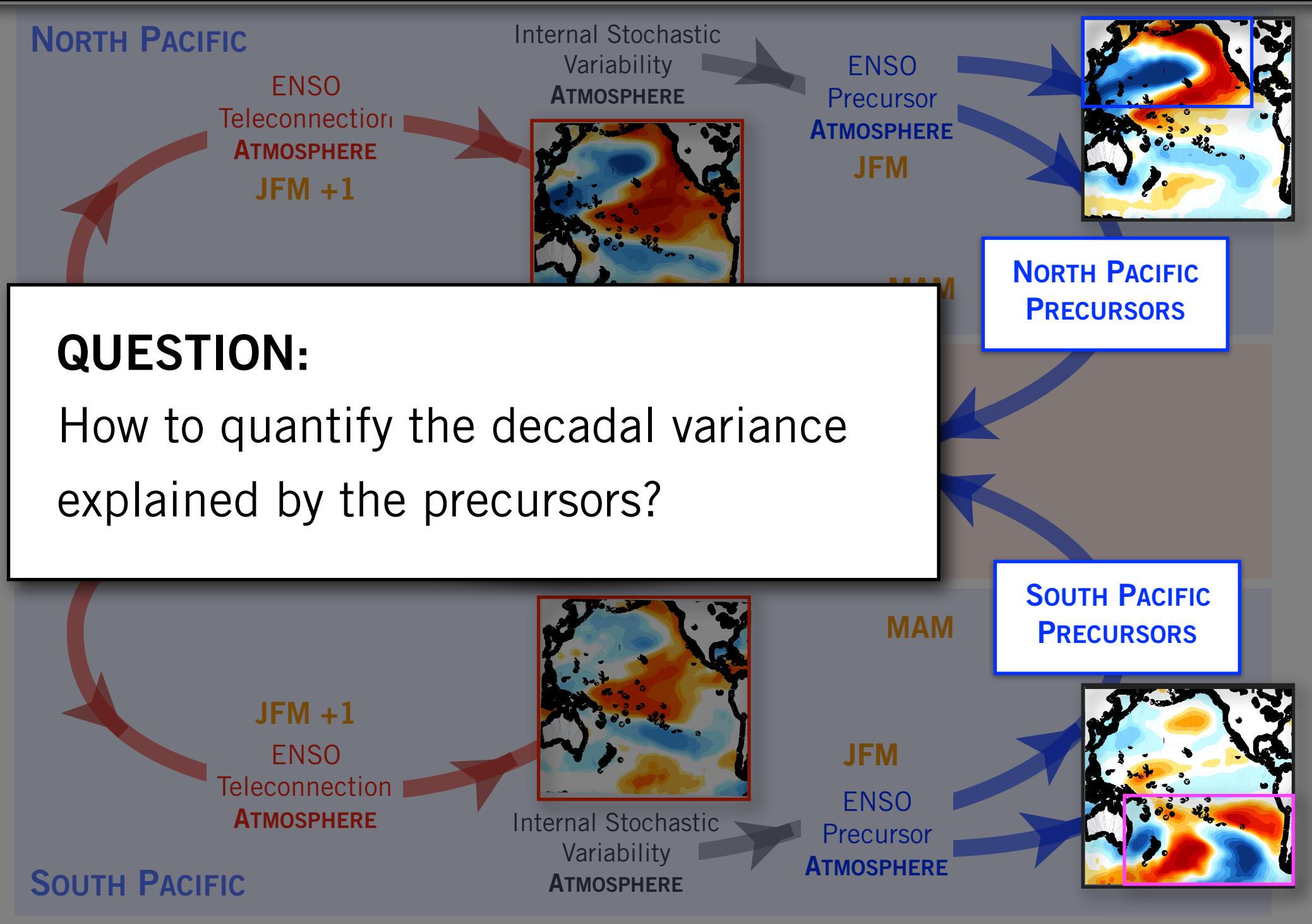
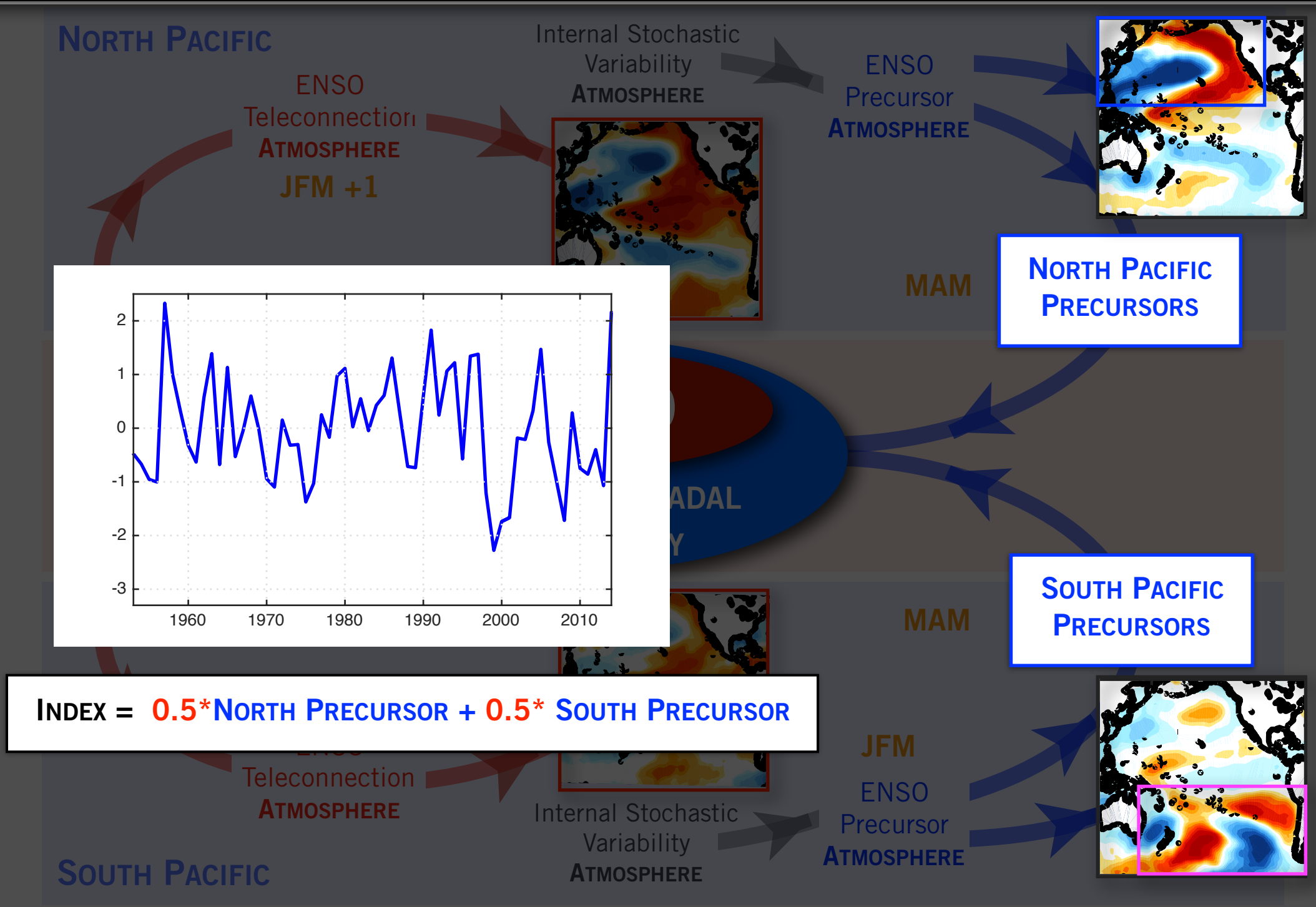


QUESTION:

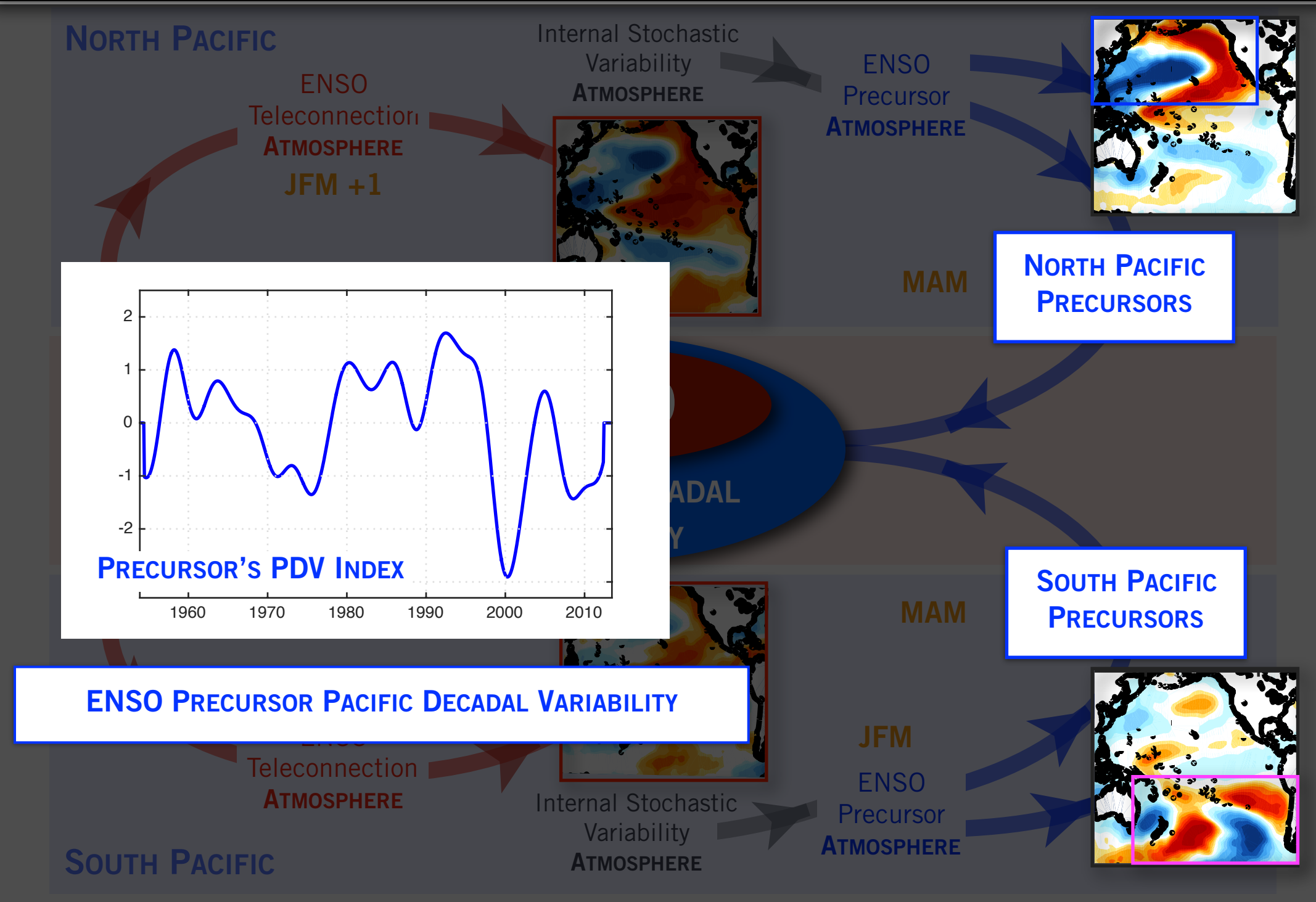
How to quantify the decadal variance explained by the precursors?

The reddening of ENSO Precursors



Index = 0.5*North Precursor + 0.5* South Precursor

The reddening of ENSO Precursors



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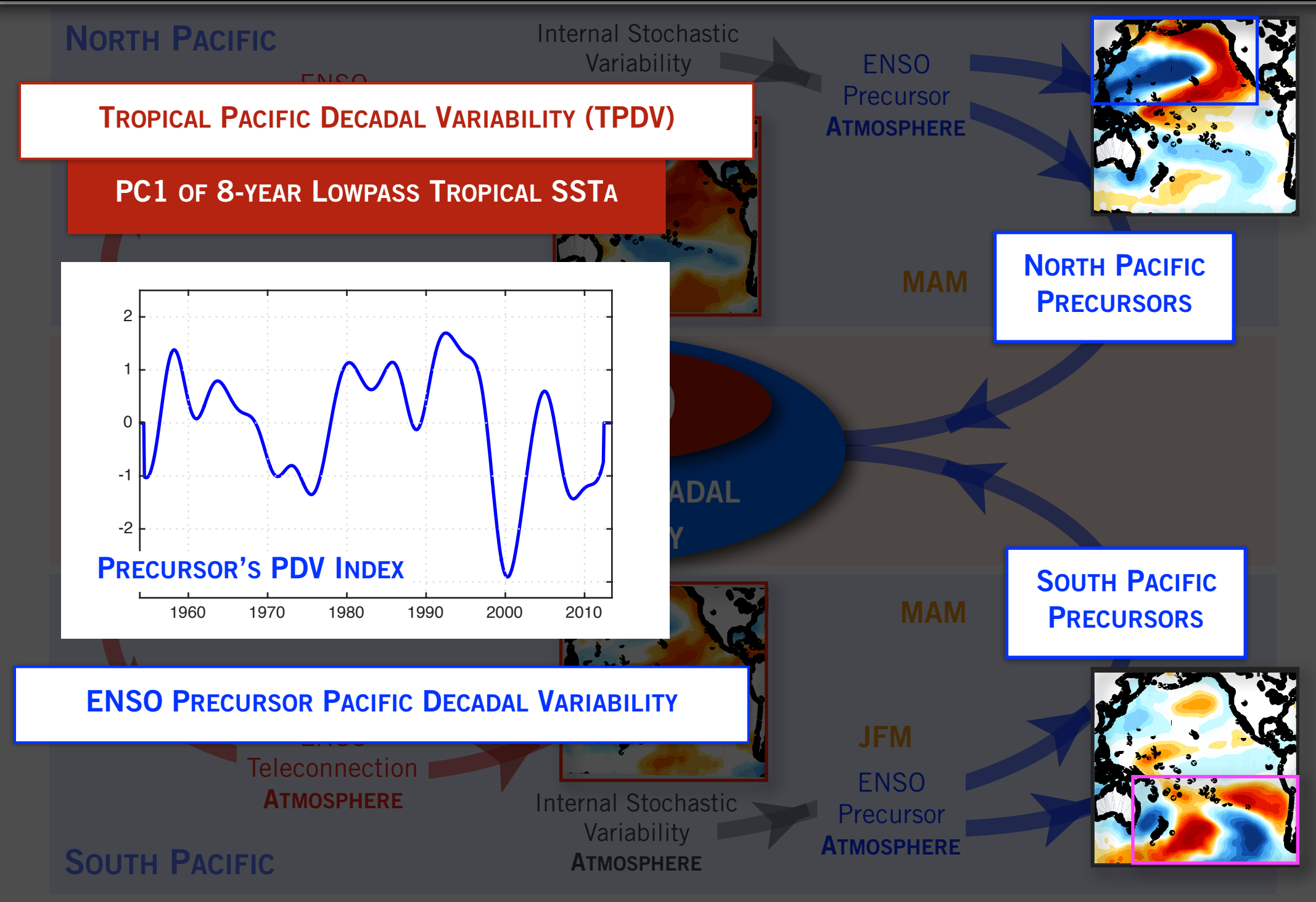
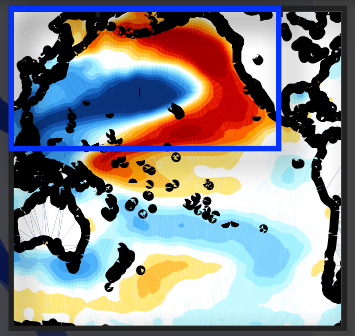


The reddening of ENSO Precursors

North Pacific

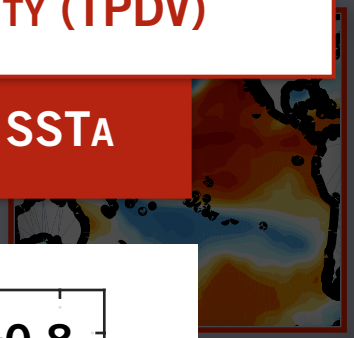
Internal Stochastic Variability

ENSO Precursor Atmosphere



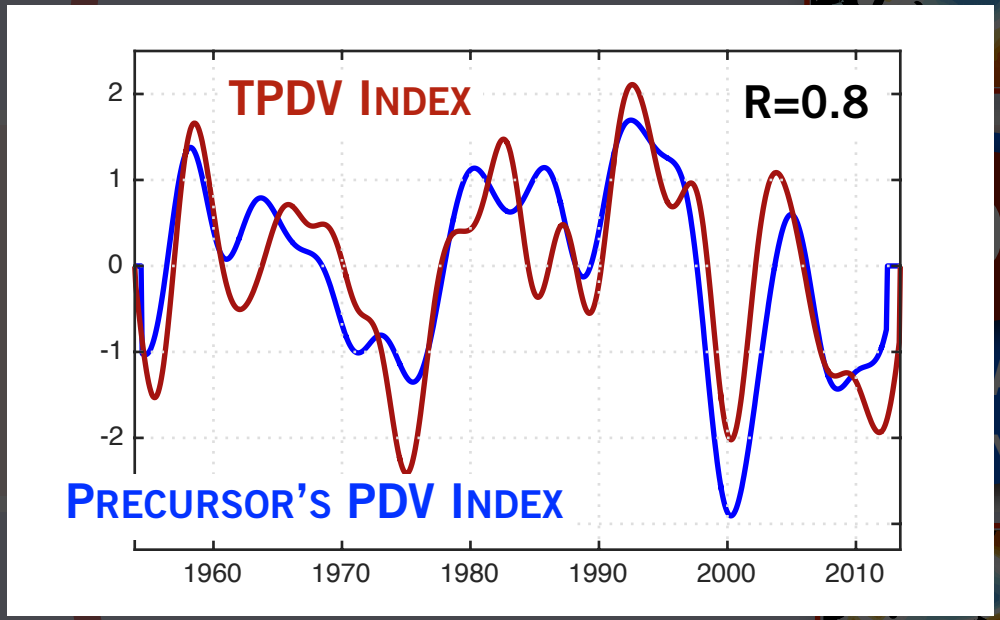
Tropical Pacific Decadal Variability (TPDV)

PC1 of 8-year Lowpass Tropical SSTa



MAM

North Pacific Precursors

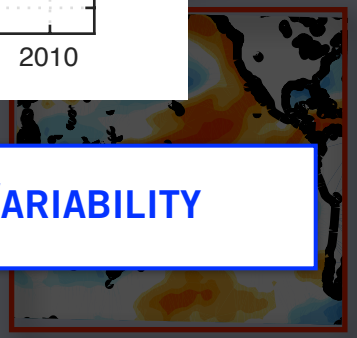


ADAL

MAM

South Pacific Precursors

ENSO Precursor Pacific Decadal Variability

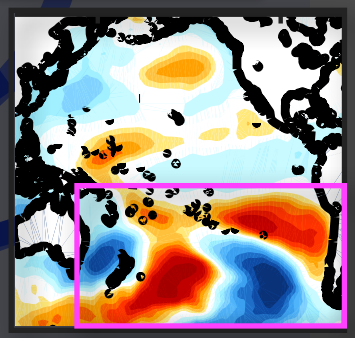


JFM

Teleconnection Atmosphere

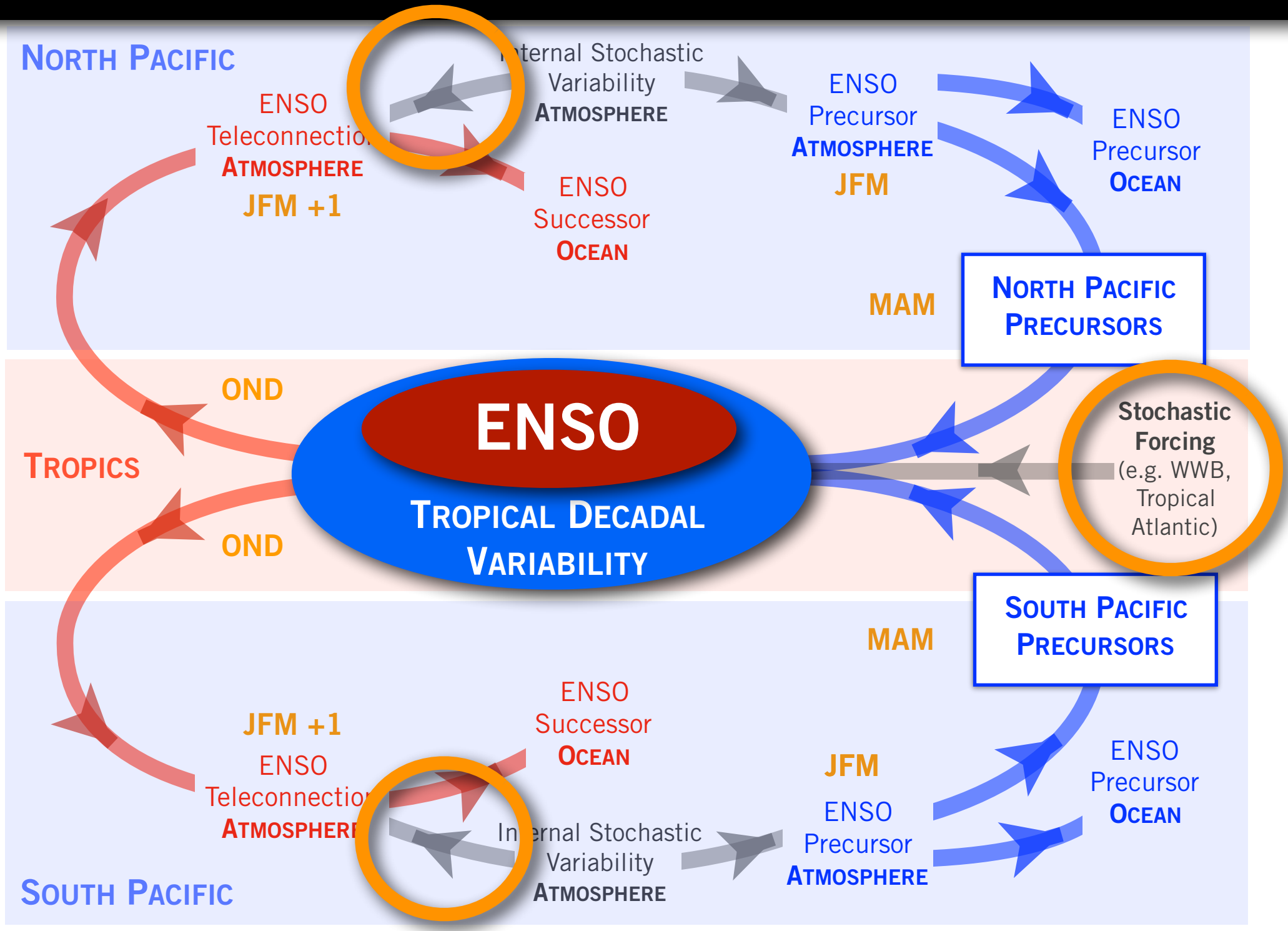
Internal Stochastic Variability Atmosphere

ENSO Precursor Atmosphere



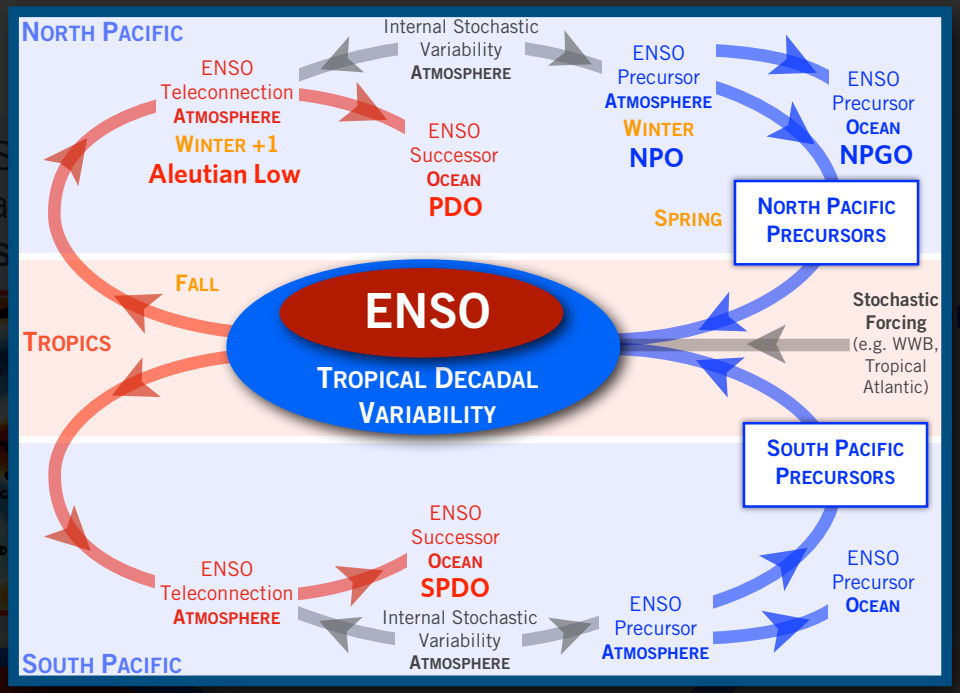
South Pacific

The reddening of ENSO Precursors

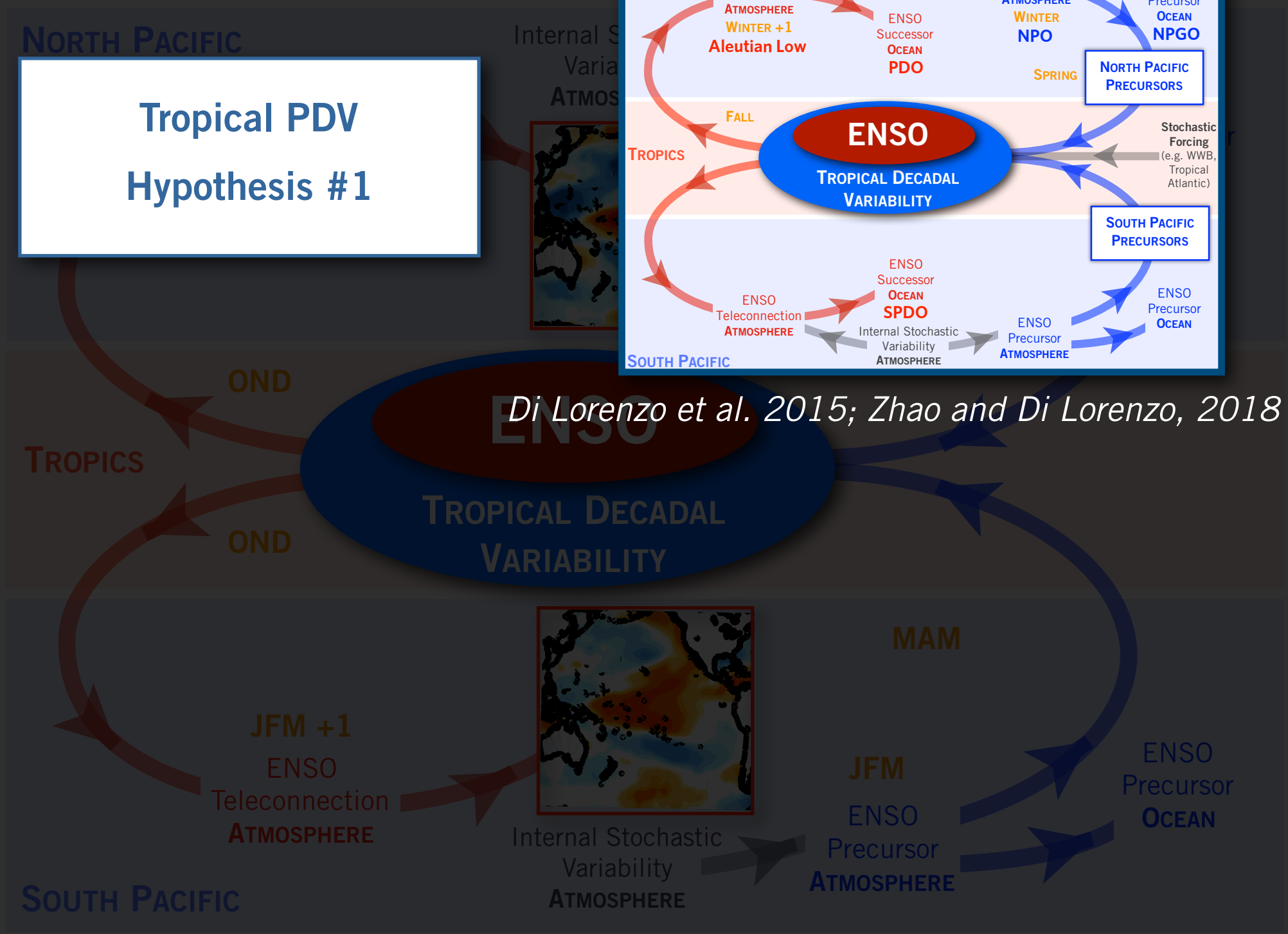


Tropical PDV

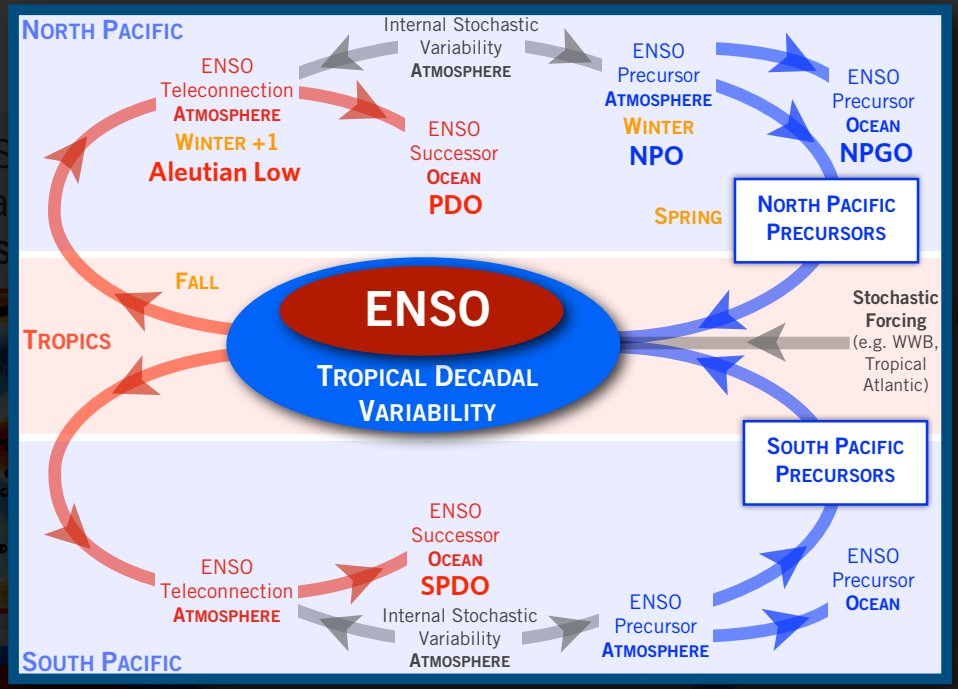
Hypothesis #1



Di Lorenzo et al. 2015; Zhao and Di Lorenzo, 2018



Tropical PDV Hypothesis #1

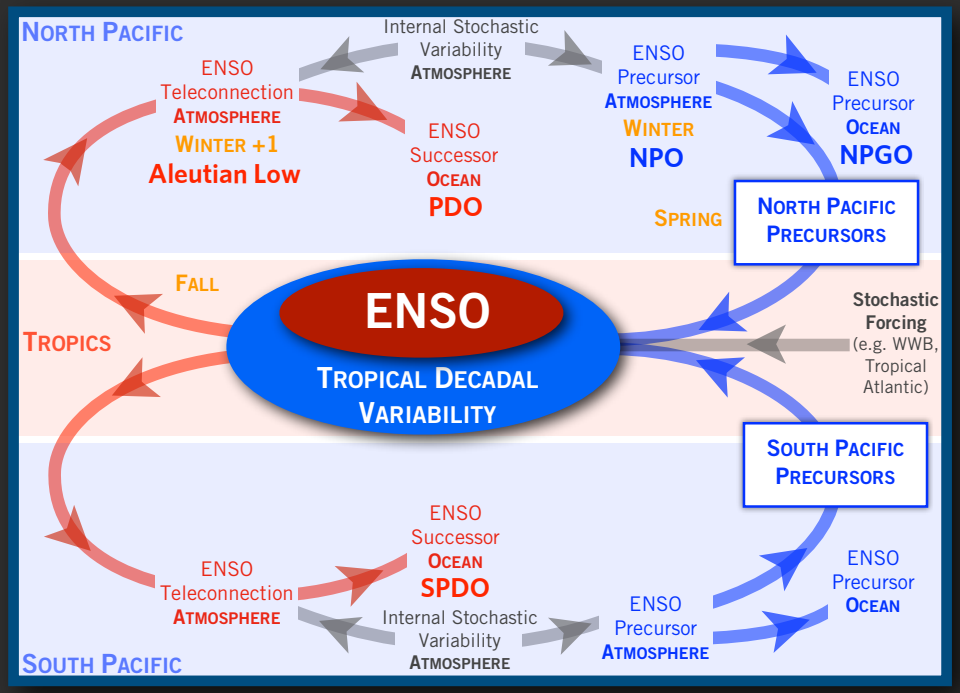


Di Lorenzo et al. 2015; Zhao and Di Lorenzo, 2018

ENSO stochastic precursors (growth) ⟹ ENSO (peak) ⟹ ENSO teleconnections (decay in the extra-tropics)

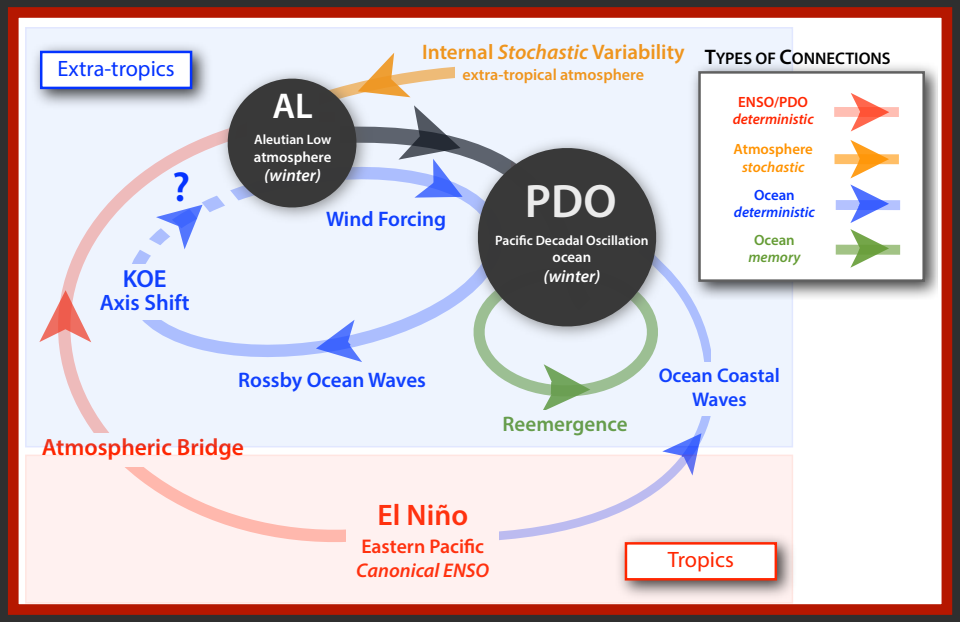
mechanism to integrate the short-memory, seasonally-varying, stochastic forcing from both the extra-tropics and tropics into Pacific decadal-scale variance

Tropical PDV Hypothesis #1



Di Lorenzo et al. 2015; Zhao and Di Lorenzo, 2018

Extra-tropical PDV Hypothesis #2



Newman et al. 2016

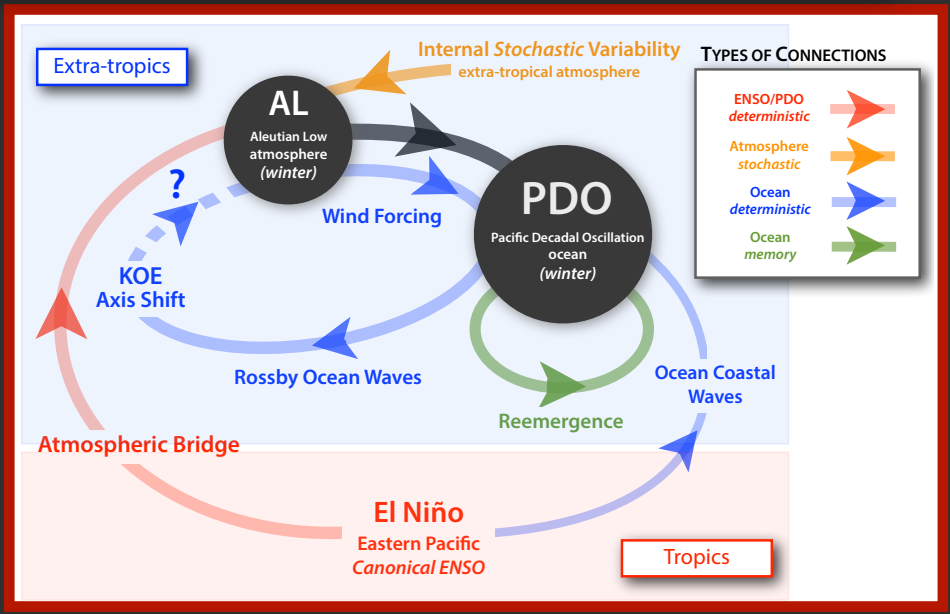
Modes of North and South PDV (e.g. PDO, NPGO, SPDO) are the result of a collection of drivers/processes:

atmospheric internal and external forcing
(e.g. stochastic and ENSO teleconnections)

memory dynamics (e.g. ocean reemergence, ocean Rossby waves, tropical/extra-tropical teleconnections)

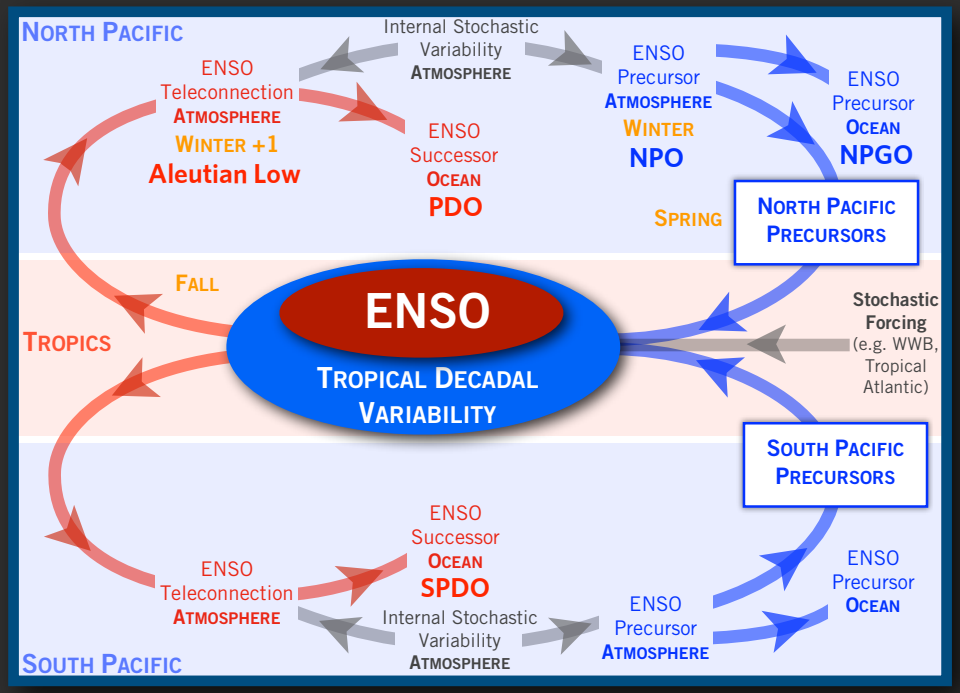
Extra-tropical PDV

Hypothesis #2



Newman et al. 2016

Tropical PDV Hypothesis #1



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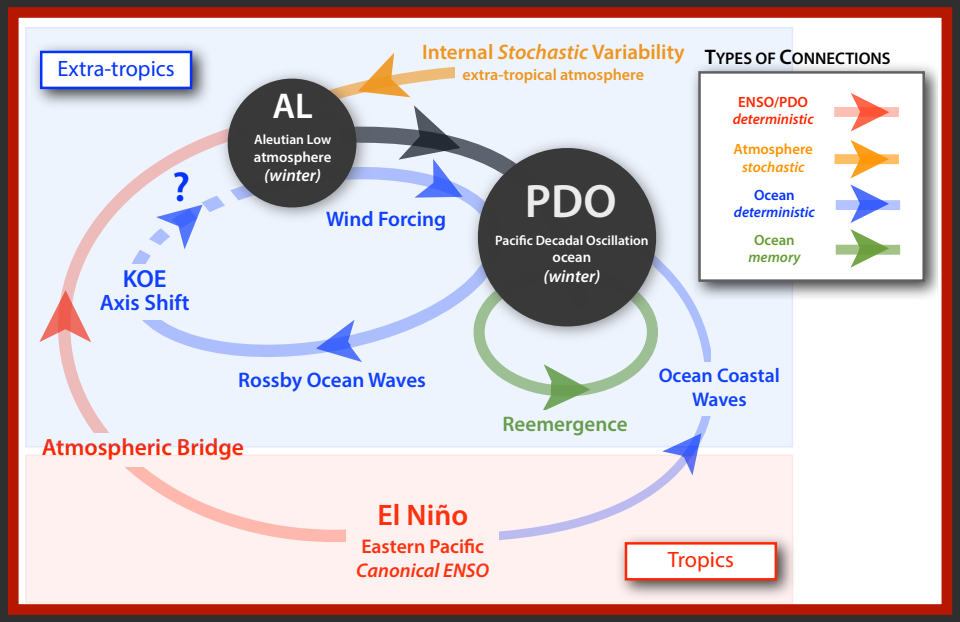
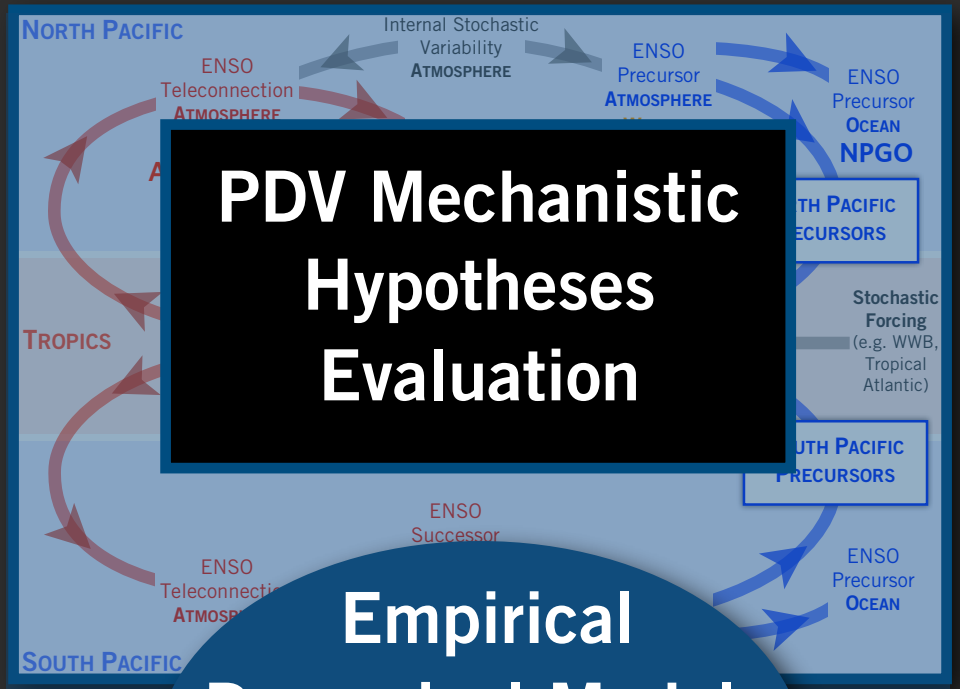
Extra-tropical PDV Hypothesis #2

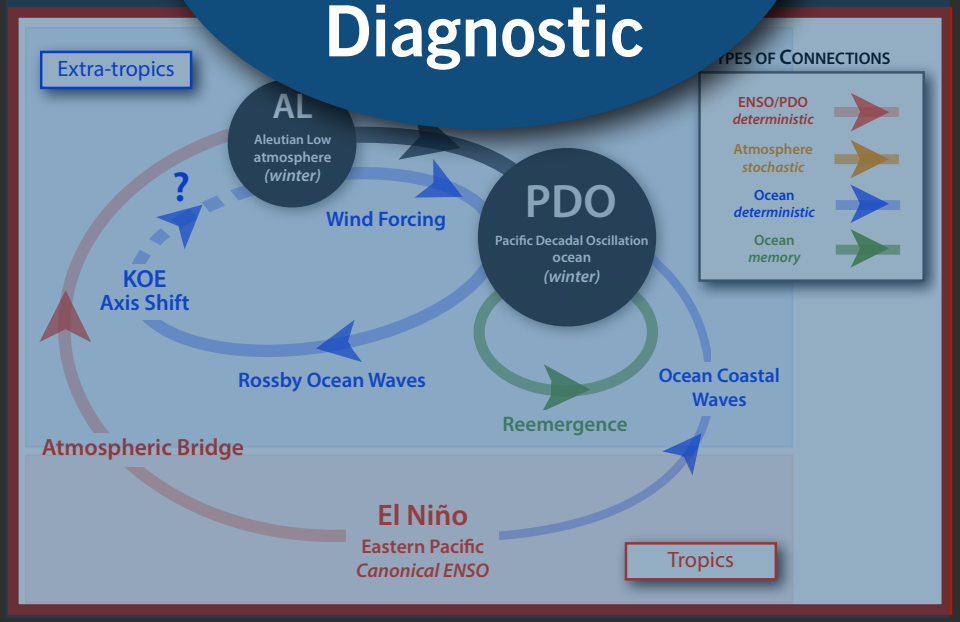


Newman et al. 2016

PDV Mechanistic Hypotheses Evaluation

Empirical Dynamical Models (EDMs) PDV Diagnostic

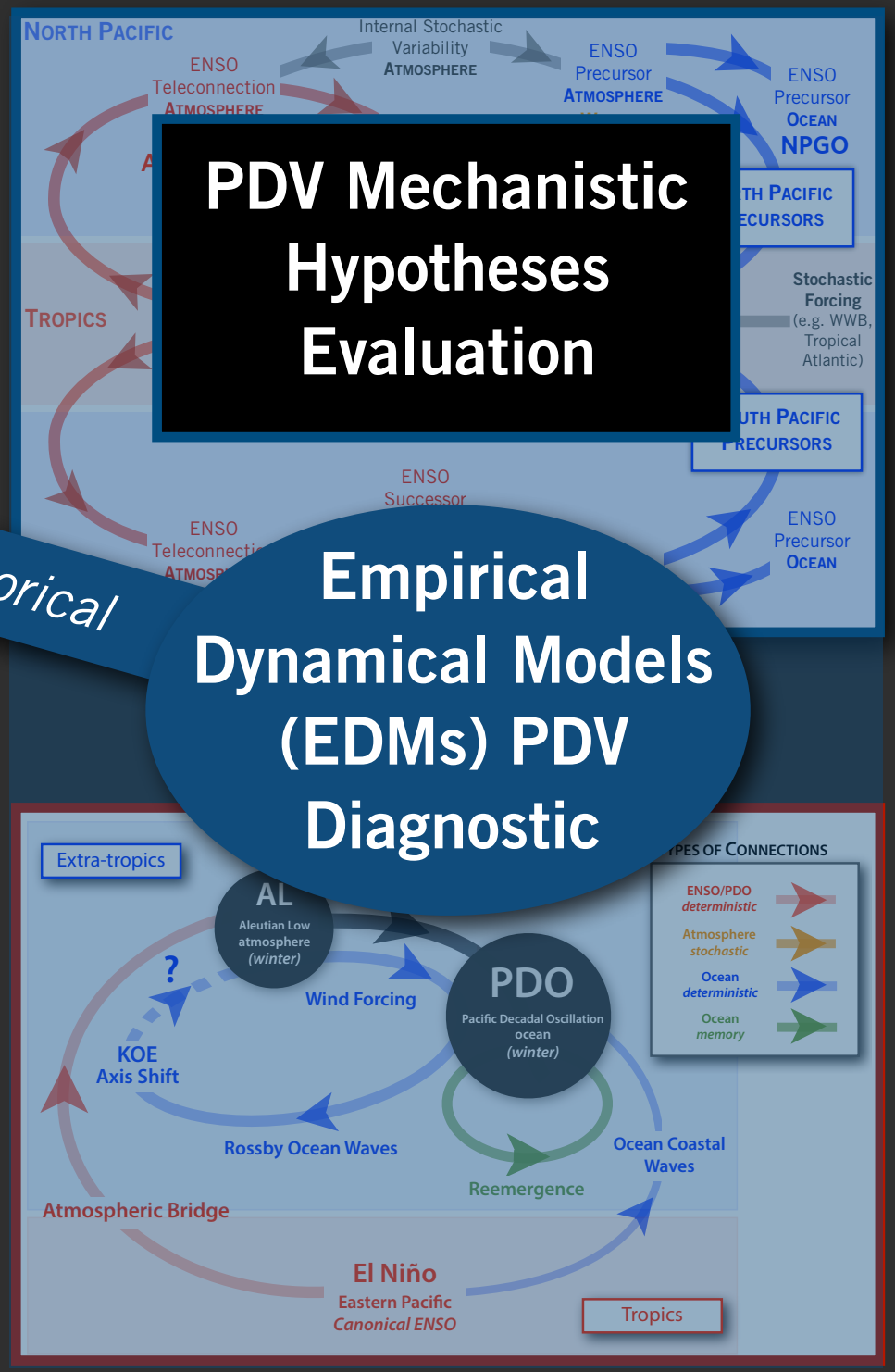




The EDMs Diagnostic Tools will be available for community with tutorials

CMIP Models

historical



PDV Mechanistic Hypotheses Evaluation

Empirical Dynamical Models (EDMs) PDV Diagnostic

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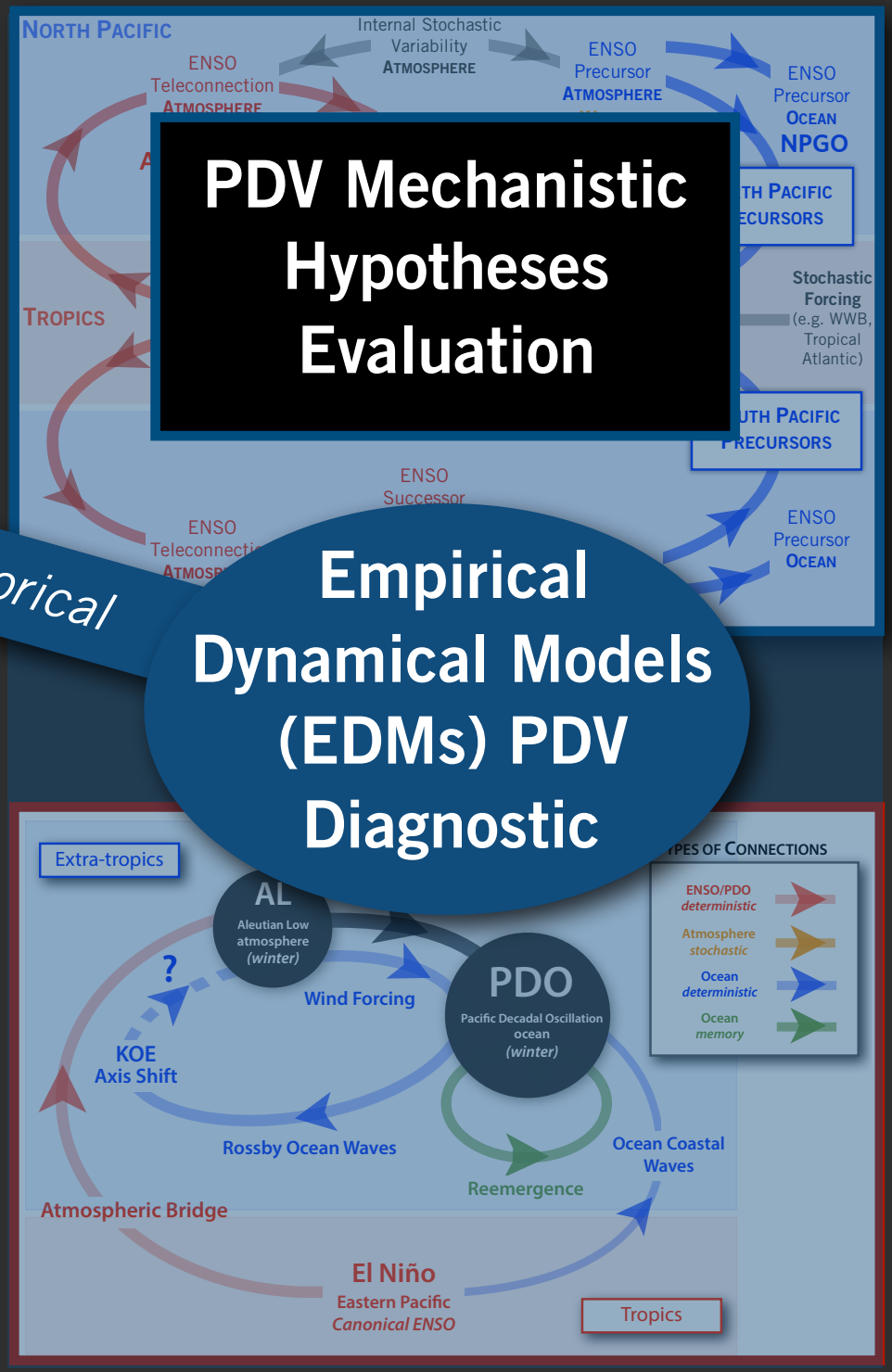
CMIP Models

historical

Empirical Dynamical Models (EDMs) PDV Diagnostic

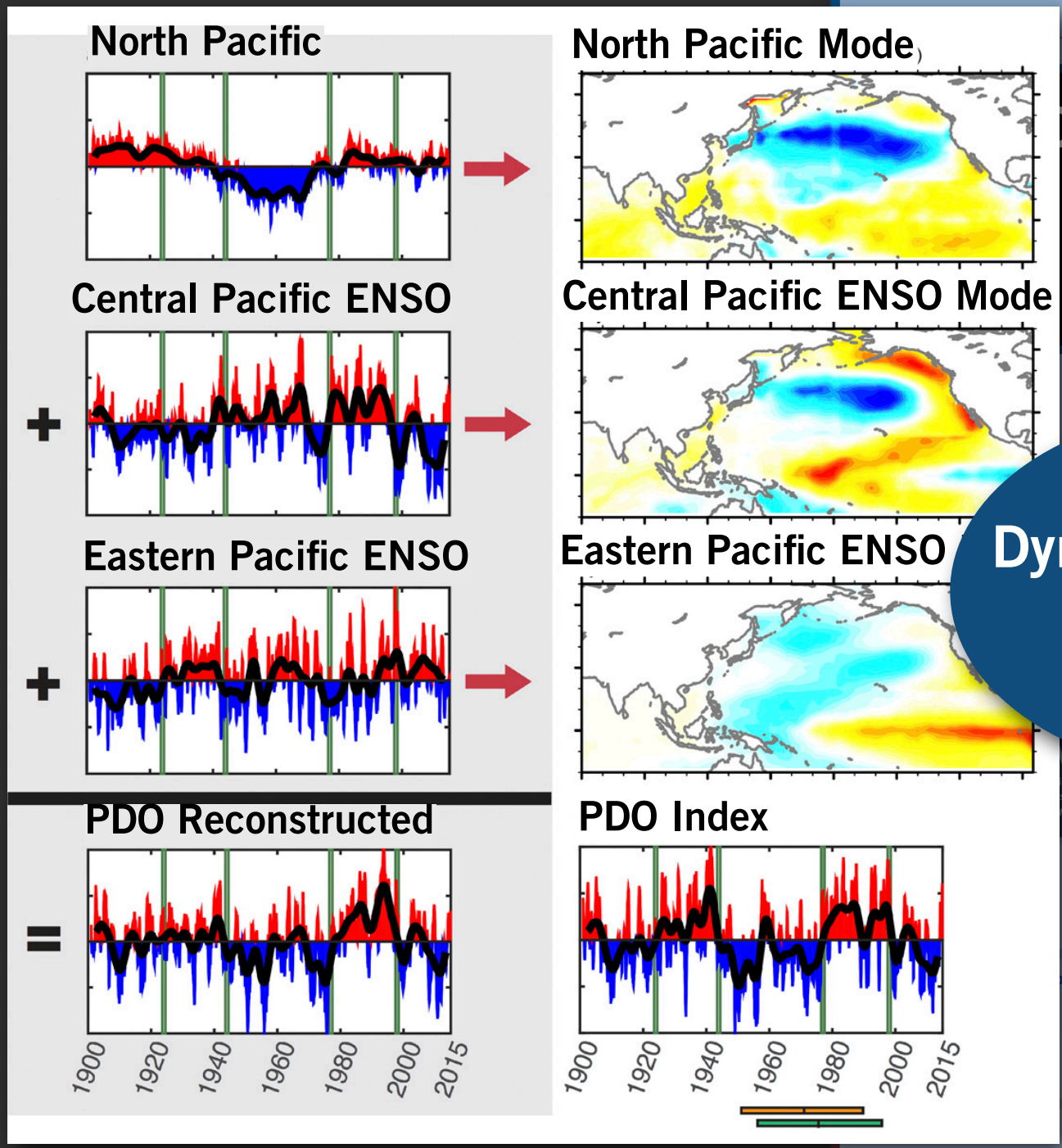


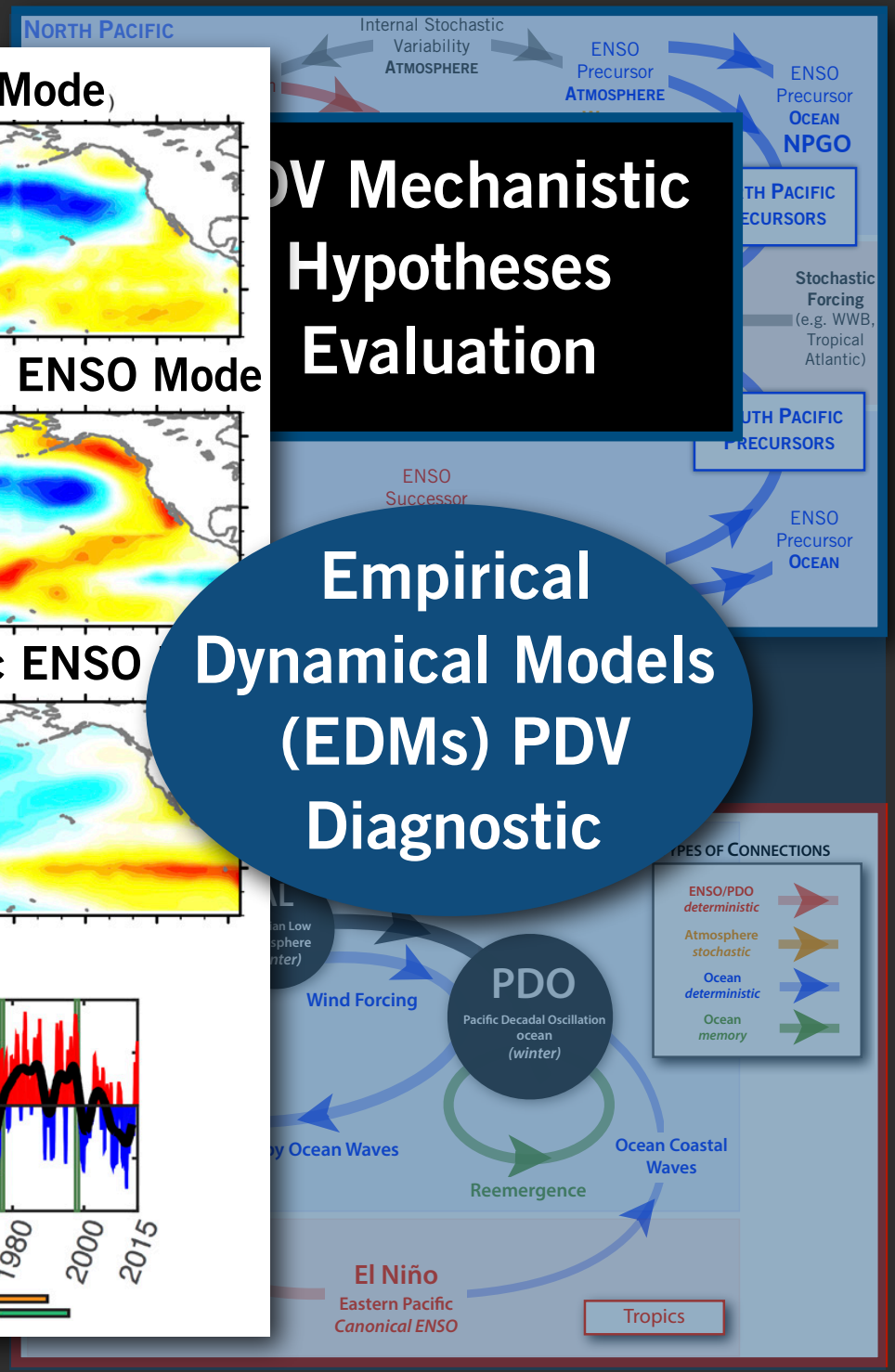
GOAL

Compare ***mechanisms*** of PDV ***not the patterns***

PDV Mechanistic Hypotheses Evaluation

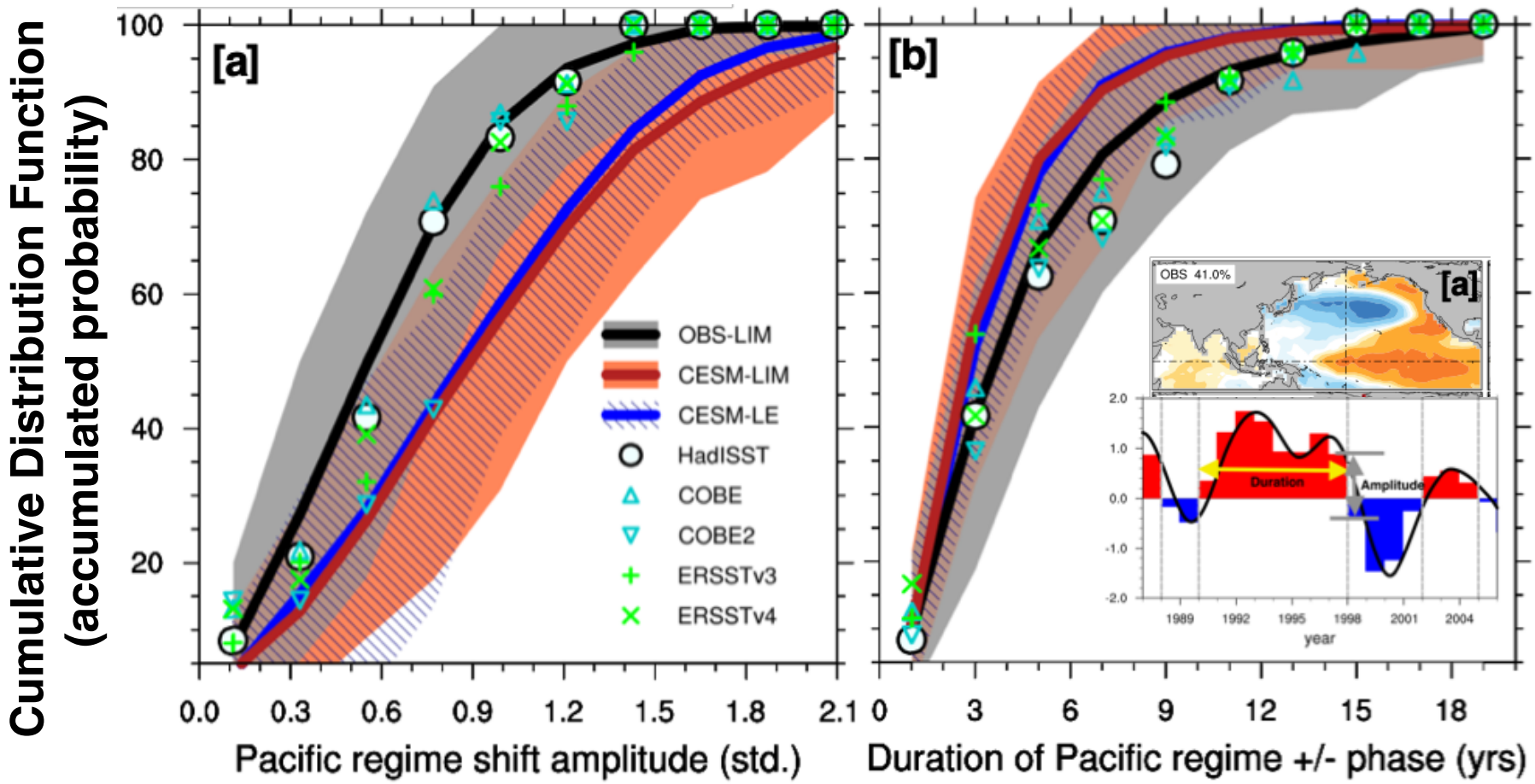
Empirical Dynamical Models (EDMs) PDV Diagnostic





Newman et al. 2016

Amplitudes & Duration of PDO transitions (e.g. regime shifts)



Newman and Kumar, 2018

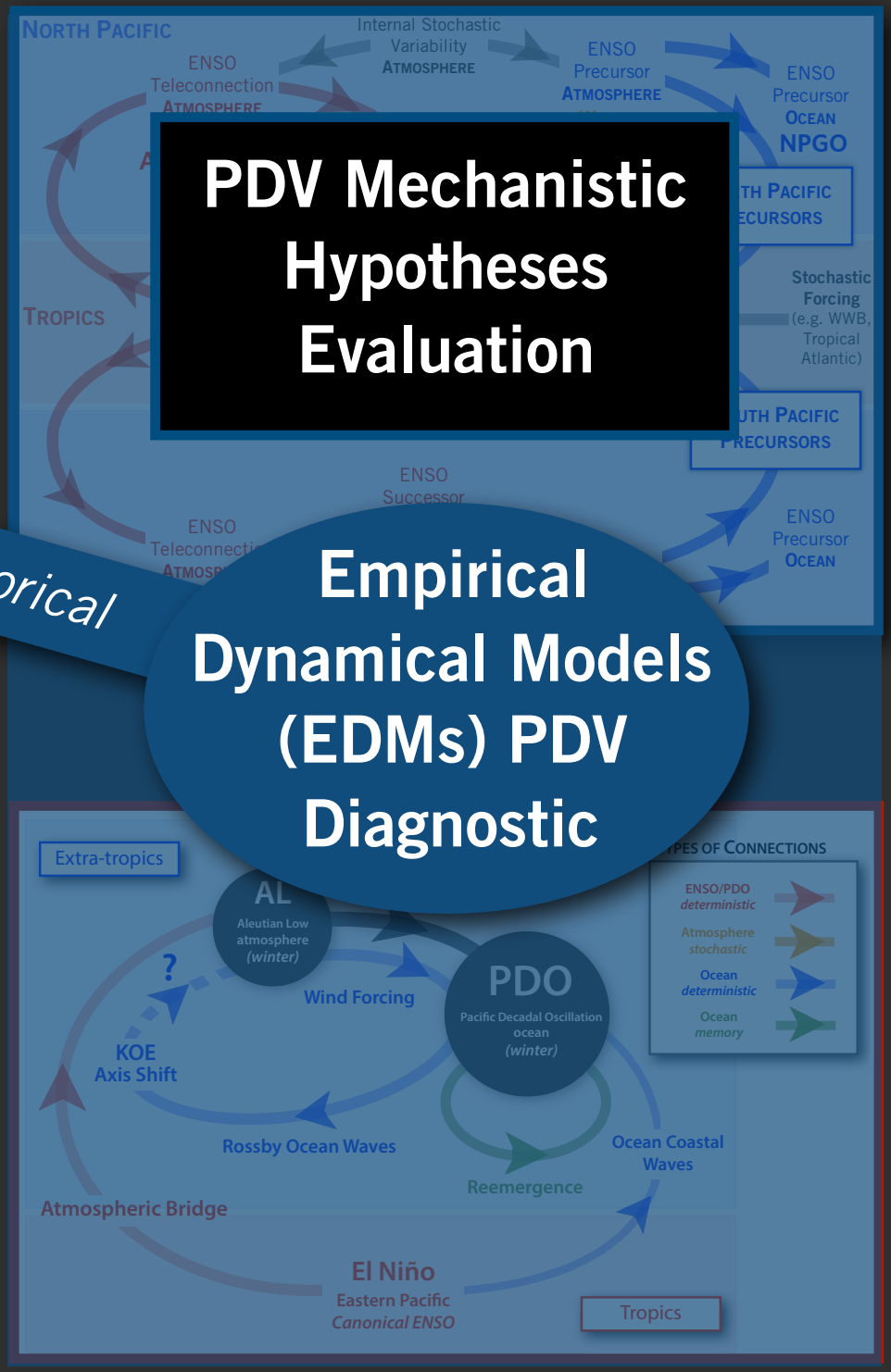
The EDMs Diagnostic & Budget Tools will be available for community with tutorials

CMIP Models

historical

PDV Mechanistic Hypotheses Evaluation

Empirical Dynamical Models (EDMs) PDV Diagnostic



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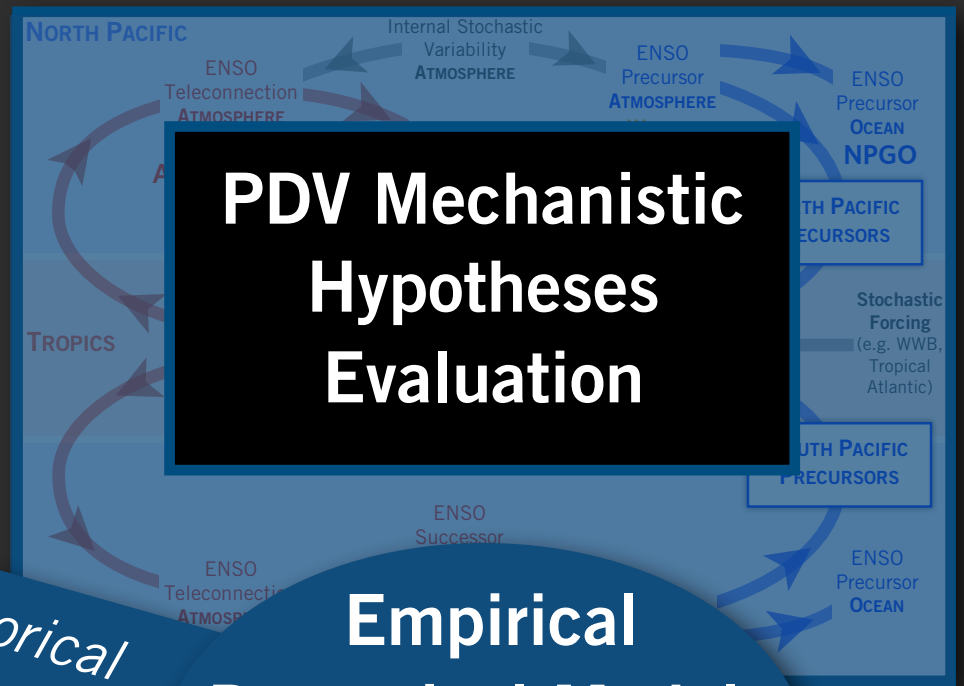
PDV Mechanistic Hypotheses Evaluation



CMIP Models

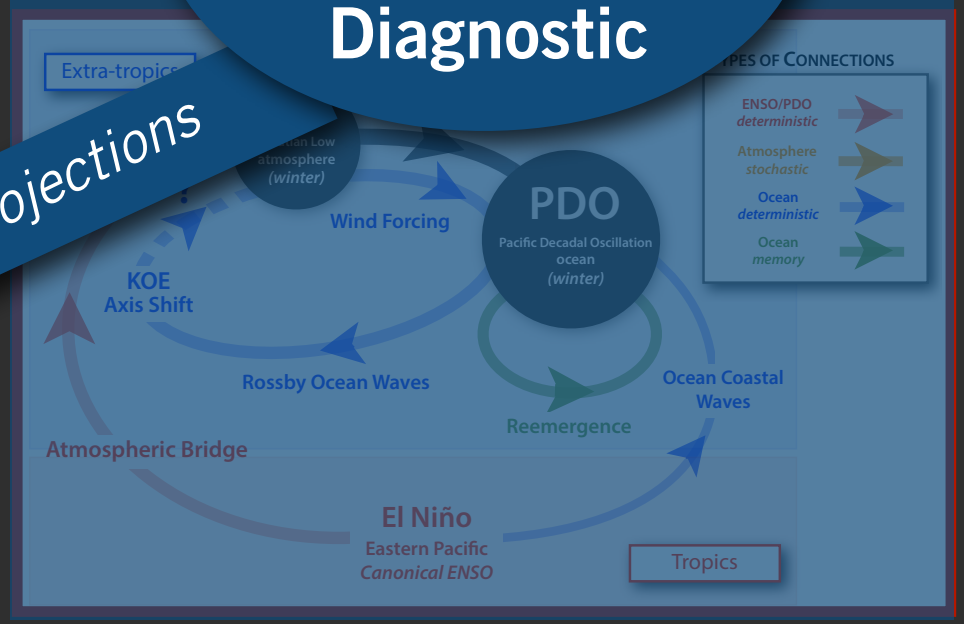
historical

Empirical Dynamical Models (EDMs) PDV Diagnostic

Large Ensembles

projections

New DOE E3SM Ensemble



Distribution of E3SM ensemble

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Large Ensembles

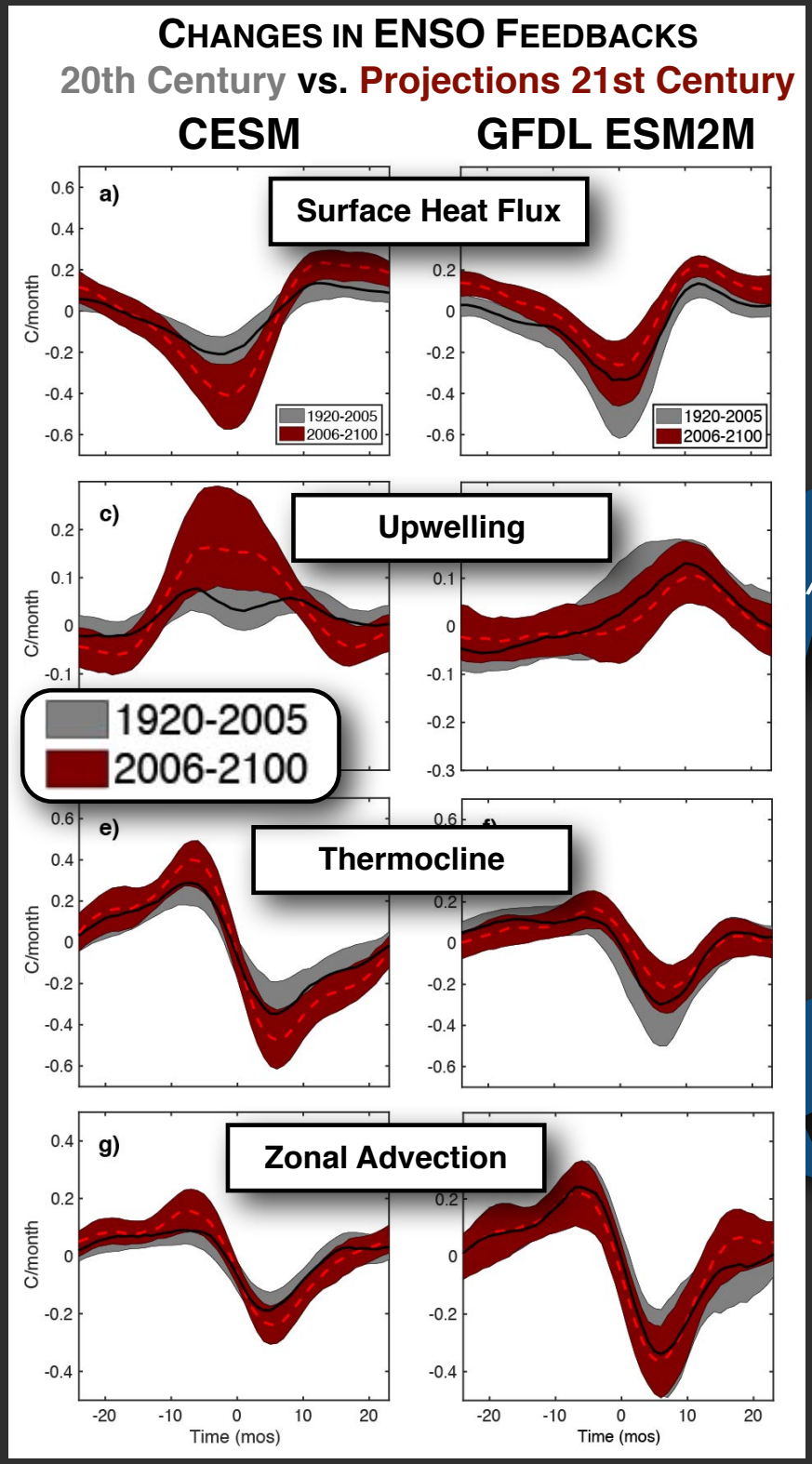
projections

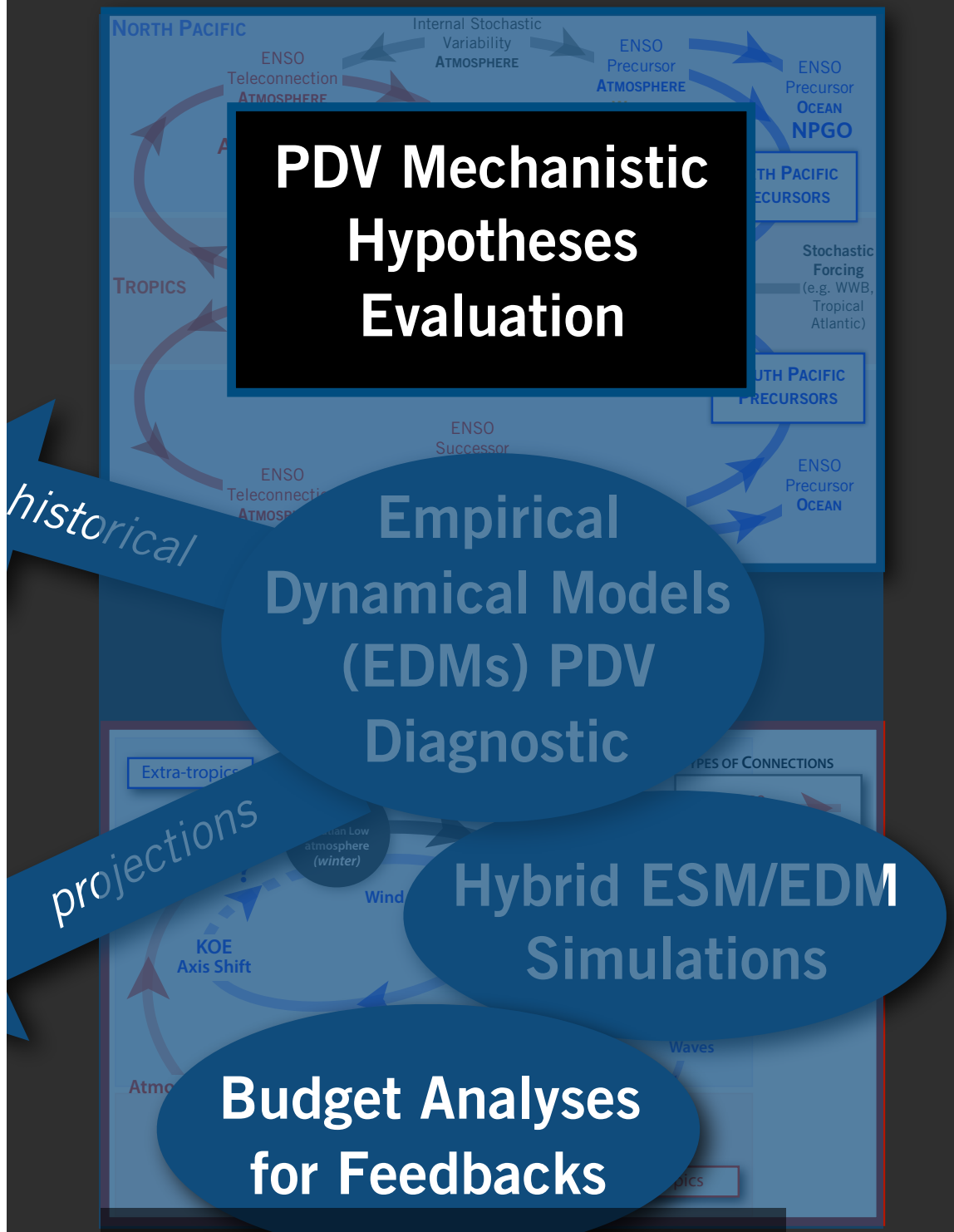
Hybrid ESM/EDM Simulations

New DOE E3SM Ensemble

Budget Analyses for Feedbacks

Distribution of E3SM ensemble





Stevenson et al 2017, Climate Dynamics

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Mechanisms of Pacific Decadal Variability (PDV) in ESMs

by Emanuele Di Lorenzo, Sam Stevenson, and Matt Newman